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THESIS

AN INVESTIGATION OF LONG TERM ACQUISITION
COST GROWTH RATES
OF UNITED STATES NAVY SHIPS

by

Douglas Arthur Smartt

March, 1983

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An Investigation of Long Term Acquisition Cost Growth Rates of United States Navy Ships

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This study is a basic exploration of the validation and limitations of forecasting the future Navy based on historical growth trends. It addresses the long term relationships between fleet dollar value, fleet tonnage, fleet manning and fleet electrical generating capacity disaggregated by classes and types of vessels in the U.S. Navy. This study presents three methods by which four aggregated growth rate relationships of United States Navy Ships may be estimated and compared. The four proportional growth rates studied are unit (ship) per acquisition dollar, tonnage per dollar, electrical generating capacity per dollar, and crewmember per dollar. The three historical growth rate computations are analyzed using four different weighting factors. Although growth rates are simplistic in concept, aggregation of the non-homogeneous collection of diverse units which compose the United States Navy provides interesting results.

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I. INTRODUCTION

A. BACKGROUND

It is the intent of this analysis to observe past historical growth rates of the acquisition cost of U. S. Navy ships and their interaction with the changes in crew size, tonnage and electrical generating capacity. These are indicators of the flow of allocating Navy resources in our changing environment to meet the Navy's mission in relation to national strategy - not just for war at sea but for peacetime missions as well. By observing the long term relationships between fleet value, fleet tonnage, fleet manning and fleet generating capacity by classes and types of vessels, this study is a basic building block in the validation and limitations of forecasting the future Navy based on these historical growth trends. It addresses a basic question of aggregation, namely: can trends be spotted in aggregated data that are not obvious when more detailed observations are examined?

The United States Navy is composed of manned ships and aircraft, both supported by a large logistic infrastructure. It is the intent of this analysis to support the policy analyst in viewing the Navy's past fleet trends and in predicting its future course in acquiring new naval vessels, by conducting a macro-analysis of Navy ship asset value changes that occur over time. Specifically, this analysis will support the ongoing Navy Resource Dynamics Model sponsored by the Office of Naval Research.

In an interview presented in the October 1982 issue of ALL HANDS magazine, [Ref. 1], two months after relieving Admiral Thomas B. Hayward as Chief of Naval Operations,

Admiral James D. Watkins stated that readiness, sustainability and modernization form the basis for our decision making goals and objectives in the U.S.Navy for the next ten years. With regard to modernizing our Navy, Admiral Watkins argued

> "We are modernizing our Navy, not just to satisfy parochial needs but because of the incredible increase in numbers and quality of Soviet Union forces. Our objectives and goals are, of course, in consonance with the fact that the United States is largely dependent upon the sea lines of communications for its survival, as are our allies."

From conception through research and development, design,procurement, and delivery, it takes a long time and an enormous effort for a new class of ships to roll down the launchway and become a commissioned vessel. All this must occur before the new class of ship becomes an integral part of the Navy operating forces fulfilling national Naval strategy. Reliable sources often state that this time frame is about fifteen to twenty years. This length of time imposes difficulty in answering the following questions: What is happening to the basic characteristic design of Naval ships and how has the design evolved? What characteristics will ships built ten years from now have? How much is it going to cost the taxpayers in the year 1995 for this new Navy ship so earnestly desired? And, how many destroyer type ships, for instance, will the Navy be able to build in the year 2000 if constrained by a certain fiscal maximum amount? It is the intent of this thesis to help answer these questions by studying relevant historical growth rates through three different methods and attempting to explain their particular results.

As previously quoted from Admiral James D. Watkins, modernization of the U.S.Navy is one of the three primary goals and objectives during his tenure as Chief of Naval

Operations. Modernization has occurred throughout history in all walks of life, however, its impact has dramatically changed the manner in which Naval seapower strategy and tactics has recently evolved. Thus, modernization of the fleet is an ongoing evolutionary acquisition process that has produced changing characteristics in Navy ships. Many factors of interest which are measurable from available data include such items as ship size, type of propulsion, standard tonnage, generating power capacity, acquisition cost, and crew requirements are detailed in Resource Allocations in the U.S. Navy: Perspectives and Prospects, [Ref. 2]. By observing the basic changes that occur in these measurable characteristics of the fleet and their ratios to acquisition cost (adjusted for inflation to constant dollars), observed costing trends will occur over time and are measurable.

It is important to discuss the various categories of U.S. Navy ships in order to maintain consistency throughout this analysis.First of all, each ship in the Navy belongs to a specific class of ship. Every ship in that specific class has the same basic design characteristics. These basic design characteristics are the same even though the ship may be built in two different shipyards on two different coasts. For example, USS Gallery (FFG-26) is an Oliver Hazard Perry class guided-missile frigate. Her dimensions, propulsion, weapons suite, crewsize, etc. are all the same as USS Oliver Hazard Perry (FFG-7), the first ship of the class. Each class of ship belongs to a particular type of ship. For example, the Brooke class and Perry class are the two classes of ship that comprise the Guided Missile Frigate(FFG) type of ship and perform approximately the same mission requirements for the Navy. The Brooke and Perry have different basic design features. For example, the Brooke class ship has a steam driven propulsion plant while the Perry class has gas turbine propulsion. Each type of

ship can likewise be grouped into major types of ships. For example, amphibious ships and aircraft carriers are two major types of ships. It should be noted that as these different categories of ships are grouped together, they comprise a mixture of characteristics. The Navy ships as a whole entity are often called the fleet or the force.

Thus, each ship class that is built can be defined in specific terms such as tonnage, speed, crewsize, etc. However, when a group of ships is aggregated together, describing the overall characteristics as it changes overtime is an evolutionary dynamic process worth studying. The concept of system dynamics which has been forwarded by Jay W. Forrester in [Ref. 3] is appropriate to the study of U.S. Navy ships. This overview to the growth process is being conducted by Dr. Rolf Clark, Research Professor of Operations Research of The George Washington University, in his Resource Dynamics Model.

Resource Dynamics is an ongoing research project for understanding naval force evolution and naval force funding requirements. It is an integrated research effort of moderate scope which complements the Planning Programming and Budgeting System(PPBS) in the Navy by independently estimating force levels and their associated budget requirements over the long term. Additionally, Resource Dynamics porvides rapid response and order of magnitude answers to Navy policy questions. As designed in [Ref. 3], Resource Dynamics provides projections into the future which are "parametrically" derived. By analyzing past trends and analyzing policies, parameters are obtained statistically, and these parameters are used to simulate the future under alternative policies. A picture of the basic diagram and interaction flow of the Navy Resource Dynamics Model is shown in Figure 1.1 .

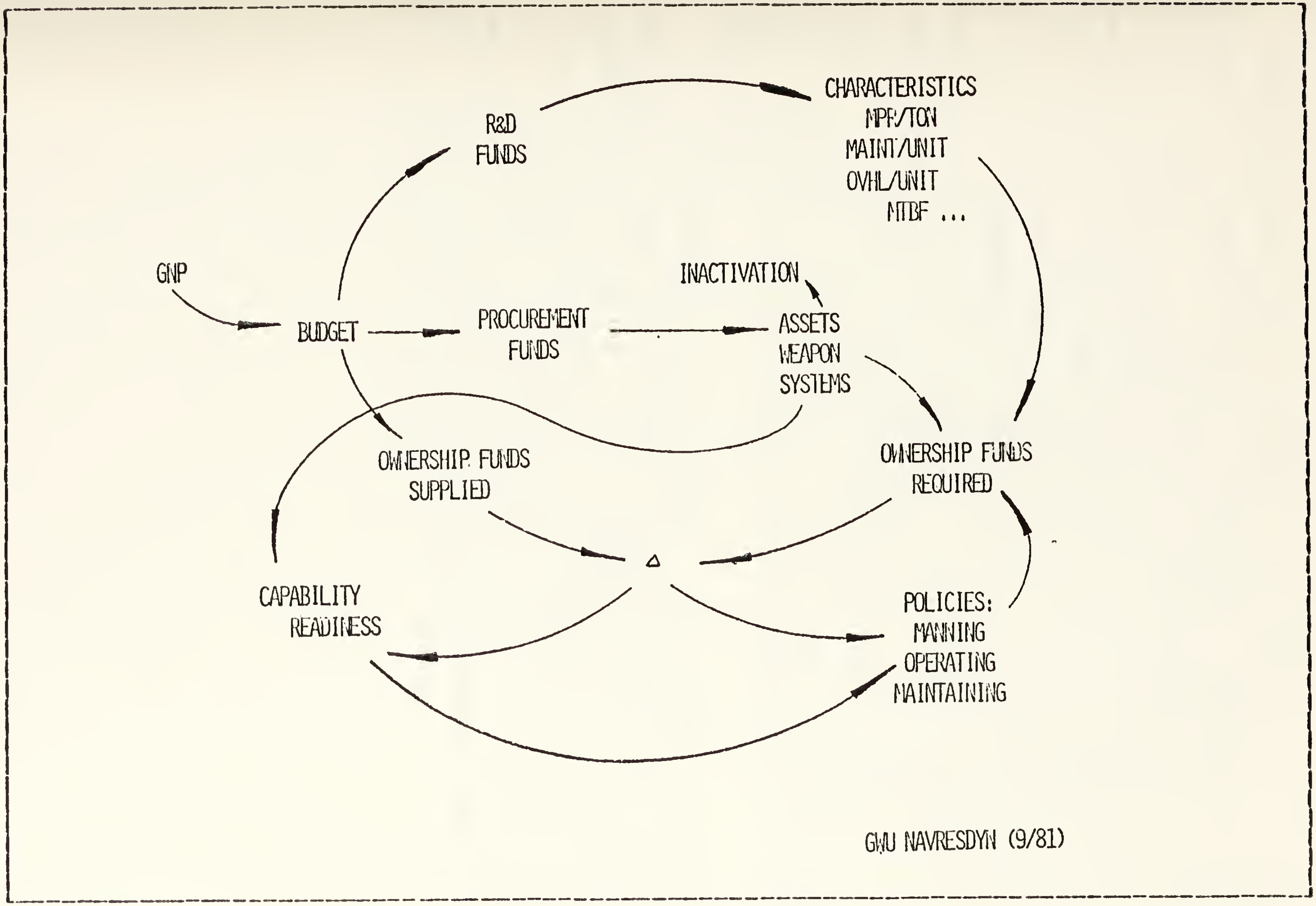

Figure 1.1 Resource Dynamics Model.

Without going into a detailed explaination, an example of a set of assumptions for the Resource Dynamics Model is shown in Table I . The resultant output from these assumptions is shown in Figure 1.2 . It is noted that there are assumptions listed in Table I which will not be addressed in this thesis. This study will not look at operating and maintenance (O&M) costs, aircraft data, modernization costs or manpower compensation costs. Ships, crewsize of ships, generating capacity of ships, and acquisition costs are investigated in this analysis. The interface with the Resource Dynamics Model in Figure 1.1 is shown in two places, namely the budget for procurement funds and the characteristics of the fleet. Thus, this study addresses only a portion of the Resource Dynamics Model and its policy implications.

The methodology with which the system dynamics, described in [Ref. 3], operates requires <u>rates</u> and ratios as primary input variables to the feedback loop of the system. Since, the primary purposes of the Resource Dynamics Model is to complement the PPBS process and to provide quick response to policy questions, it is important that the rates and ratios provided for the modelling process accurately describe the flow of resources in the system.

TABLE I

Resource Dynamics Model Sample Assumptions

--Budget Growth(from 1982 on):15,7,7,7,7,7,1.5,1.5,(%)

--Ship Size Growth Rate: 1%

--Generating Capacity per Ton Growth Rate: 1%

--Aircraft Unit Cost Growth Rate: 3.8%

--Flight Hours per Aircraft: 378(BA-1 Acft),282(Others)

--Ship Maintenance as Percent of Acquisition Cost: 3.8%

--Acft Maintenance as Percent of Acquisition Cost: 6%
(Fixed Wing 5%,VSTOL 10%,Rotary 15%)

--Maintenance Cost on Units over Service Life is Doubled

--Real Compensation grows 2% annually

--Fuel Cost grows 5% annually

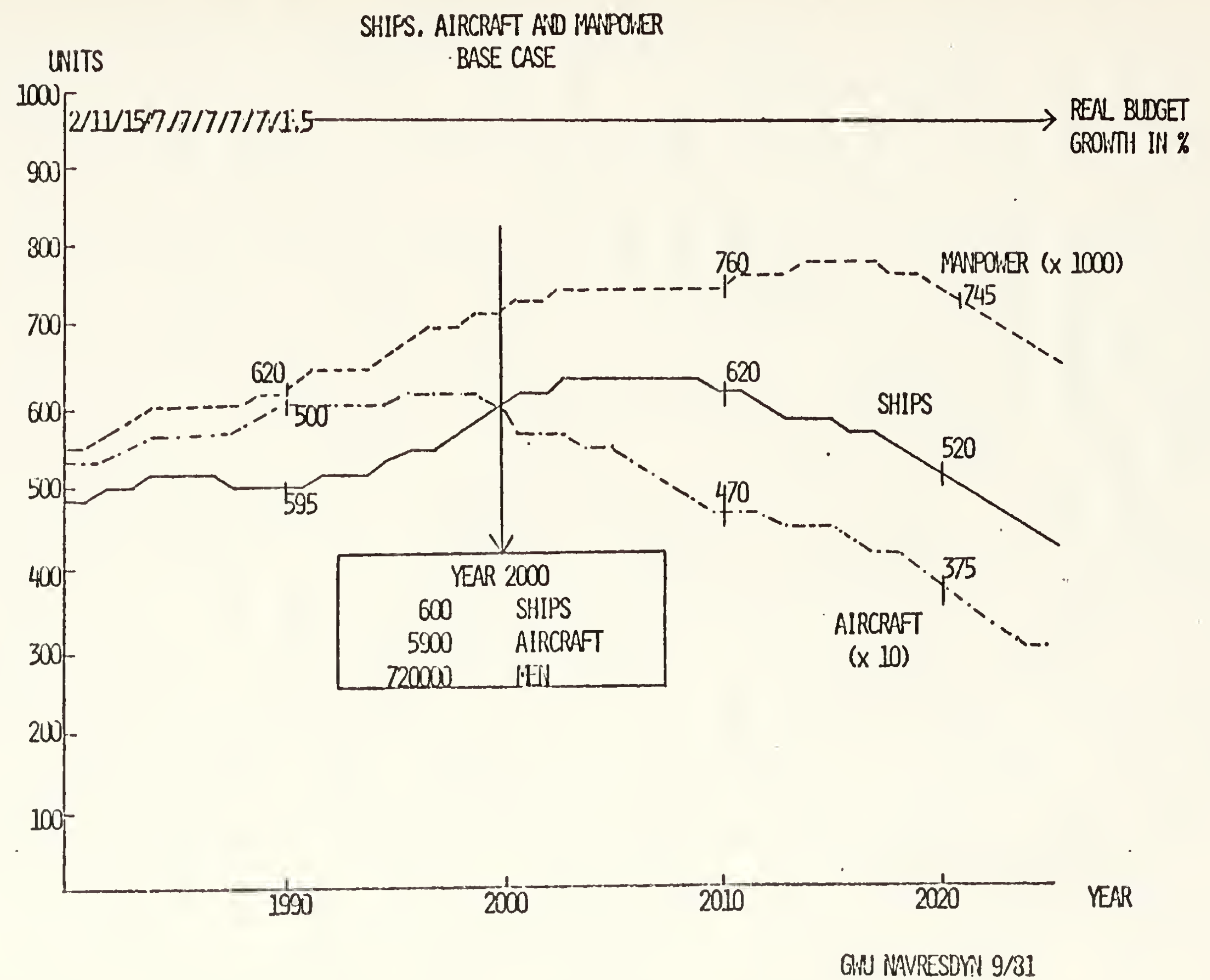

Figure 1.2 Resource Dynamics Model Sample Results.

Thus, the study of empirical proportional growth rates for U.S. Navy ships and the subsequent flow of resources and technology in this analysis are expected to be integrated into the ongoing Navy Resource Dynamics Model. One of the input features of Dr. Clark's model is ship unit cost characteristics growing from historical rates, adjusted for recent trends and adjusted for complexity changes. This study is a re-examination of the basic ship proportional acquisition cost growth rates. By attempting to disaggregate in various ways and utilizing various computer methods to try to produce the best overall growth rates and also produce the best type of ship growth rates, this thesis will provide these options and their limitations as an updated input for Dr. Clark's Resource Dynamics Model.

The proportional growth rates to be studied in this analysis are units per dollar (asset value), generating capacity per dollar, tonnage per dollar, and crewsize per dollar. Two relevant questions to this analysis are: Why should these particular proportional growth rates be studied? and Why are all four growth rates expressed as "per dollar" (or asset value)? Classical economic theory has three traditional inputs to a production function. These are manpower, energy and equipment. All three of these are represented in this analysis. Additionally, as in most business decisions, capital or the budget funding availability drives the acquisition decision-making process. Within the Department of Defense, the one variable which can be indirectly controlled is the budget. The other explainatory variables are for the most part fixed. Thus, through the use of proportional growth rates (per dollar), this study attempts to help translate the budgetary considerations to the observable element of the Navy's production function which is the composition of the fleet. By studying the

exogeneous variables as trends in relation to ship value, the resultant policy implications become more observable for the decision makers.

The proportional growth rates studied in this analysis are not so easily obtained in the Navy because their effects on the classes of ships are not the same. Not only are the ship class characteristics not the same, but the new classes created over time have different characteristics as well. This difference in the Navy's ship class characteristics is the reason that weighting factors must be utilized in aggregating the various non-homogeneous types of ships. A strong trend may exist in a particular class of ship. Yet when the class is grouped with similiar ships into its major mission type, the impact is minimized. The ship's uniqueness may be overpowered in quantity or cost of other classes. Therefore,even if a trend is strong in a particular class of ship it may not affect the total Navy trend because it is such a small input to the whole fleet. For this reason it is important that the "best" overall proportional growth rates are utilized. "Best" implies smoothness,consistency and stability. To answer the design question of what the characteristics of a new class of destroyer built in the year 2000 will be , requires the assumption of consistent, smooth growth if the system dynamics concept is utilized to solve it.

The United States Navy is not only changing in quantity of ship forces but in mix as well. Before devising his Navy Resource Dynamics Model, Dr. Clark conducted the historical stock and flow analysis of the Navy from 1962 to 1977. This analysis was published as Resource Allocations in the U.S. Navy: Perspectives and Prospects. This document served as the date base and conceptual basis for the Resource Dynamics Model. An update on the general change in fleet composition and individual ship characteristics as presented in that working paper, [Ref. 2], follows:

It is appropriate to digress briefly and mention the ship classes leaving and entering the fleet during the historical period of interest in this analysis. The period 1962-83 saw the exit of many remaining World War II ships--the Hancock and Essex class aircraft carriers, the Des Moines, Saint Paul, and Canberra class cruisers, the Sumner, Gearing, and Fletcher class destroyers, and the Edsall class escort all left the fleet. Only a few of the most recent diesel submarines remained. The Guppy classes are decommmissioned and are replaced by nuclear subs. The Desoto County, Terrebonne Parrish, and Tablot County landing ships (LST's) are gone and have been replaced by larger, faster amphibious ships. New classes have names already famous: the ballistic missile submarines (SSBN) Lafayette, Ethan Allan, George Washington; the Los Angeles, Sturgeon, and Narwhal class fleet submarines (SSN); the Nimitz CVN, the Virginia, California, and Belknap cruisers, the Spruance class destroyer, and the Brooke, Garcia, Knox, and Perry class frigates, all have made their debut. Amphibious forces saw the introduction of the new Tarawa-class helicopter assault ship (LHA). Many names--too numerous to mention all--remained active throughout; Tullibee, Enterprise, Kitty Hawk, Forrestal, Midway, Long Beach, Bainbridge, Adams, are a few.

Dr Clark's synopsis of the changes in the composition of the Fleet is still appropriate to this analysis covering 1962 to 1983. In [Ref. 2], Professor Clark stated:

> "The data in this analysis is made up of such individual ships. Slowly but noticeably, their procession changed the characteristics of the fleet. The fleet is faster, more crew-conscious, and more powerful than before.
>
> During the 1962-77 period the mix of ships changed and so did the characteristics of individual ship types. There are fewer ships now and less total tonnage. Large increases in submarines and decreases in aircraft carriers and surface combatants have occurred. Mine force ships have practically disappeared. Amphibious ships stayed relatively constant in number. There now

are larger ships with more nuclear propulsion, older carriers and SSBN's, and different amphibious forces."

With so much change in the composition of the force, it is difficult to easily see relationships, most especially proportional rates, that are constant in U.S. Navy ships. This thesis searches for those relationships that are the driving influences to the acquisition cost process. For that reason, unit per dollar, crewsize per dollar, generating capacity per dollar, and tonnage per dollar are the four growth rates studied. They help define the evolutionary process of changes in the fleet, providing insight on the future direction of the fleet as it continues to modernize. And, they are derived to directly assist Dr. Clark in his ongoing Resource Dynamics model.

B. INTRODUCTION OF A NEW CLASS OF SHIP

Before observing the data base it would be beneficial to observe the effect of the proportional growth rates when a new class of ship is introduced. The Spruance class destroyers have been selected as an example for introduction of a class into the fleet. The pertinent basic data on the Spruance class is displayed in Table II .

The Spruance class destroyer was the first destroyer (DD) to be introduced in the fleet since the last Forrest Sherman/Hull class ship, USS Turner Joy (DD951), was launched in 1958. There were numerous guided missile destroyers (DDG), frigates (FF), and guided missile frigates (FFG) introduced during this intervening time period of 1958-1973. Concurrent with the introduction of the Spruance class destroyers in the 1970's was the decommissioning of numerous Gearing, Carpenter, English, Allen M. Sumner, and Fletcher class destroyers. All of these destroyers were built shortly before, during, or shortly after World War II.

TABLE II

Spruance Class Basic Characteristics

Name	Acquisition Cost in 1984 Dollars	Standard Tonnage	Crew Size
Spruance	377,869,000	7,300	353

Generating Capacity	Launch Year	Number in Commission Now
6,000 KW	1973	30

However, these graceful "Greyhounds" of the fleet were becoming obsolete in terms of technological capability to fight the modern Soviet threat and were reaching the end of their maintenance sustainability.

The Spruance class destroyer was conceived, designed and analyzed in the mid 1960's as a replacement for the aging World War II destroyers. Although it was an inevitable requirement to build a new class destroyer, Admiral MacDonald, as Chief of Naval Operations was the insrumental catalyst that began the gestation of design and planning for a replacement destroyer. Its analytical requirement was solidly based upon the Major Fleet Escort Force Level Study, [Ref. 4]. This Chief of Naval Operations study was published in August,1967 and it strongly influenced the characteristics of the Spruance class. After engineering design plans were formalized, the Fiscal Year (FY) 1969 New Construction Program requested funding for the first five ships of this class. The funds were denied by Congress. In the Fiscal Year 1970 Program, Congress approved funds for the construction for five ships. However, due to increasing

costs, the Department of Defense was forced to construct only three ships under the FY 1970 program.

USS Spruance,the lead ship of the class, was launched 10 November 1973 and was commissioned 20 September 1975. Thus, she took approximately two years from launch to commissioning and was effectively introduced to the fleet in early 1976. Four more Spruance class destroyers were commissioned in 1976, followed by five in 1977, eight in 1978, seven in 1979, five in 1980 and one to be commissioned in 1983.

Jane's Fighting Ships [Ref. 5] provides an overall synopsis of the Spruance class characteristics. She is designed with an extensive use of the modular concept to facilitate both initial construction and block modernization of the ships. The ships are highly automated, resulting in about a 20 percent reduction in personnel over a similiar ship with comparable systems.

The primary mission of the Spruance class destroyer is anti-submarine warfare including operations as an integral part of attack carrier task forces. These ships are the first large U.S. Navy warships to employ gas turbine propulsion. Each ship has four general electric LM 2500 marine gas turbine engines and control pitch propellers. The ships are fitted with advanced self-noise reduction features. Three gas turbine generators are installed, each with 2000 kilowatts of generating capacity.

Each Spruance class ship has a standard displacement of 7,300 tons and is historically large for a destroyer. She carries a wartime,onboard complement of 353 crewmembers. Each ship of the class has the same characteristics as USS Spruance except for the acquisition cost. Thus, tonnage, crewsize and generating capacity are all the same for each ship of the class and acquisition cost is the only major difference between units of the class.

The acquisition cost for each ship is different, even when adjusted for inflation (constant year dollars). In shipbuilding as well as other industries, it is a standard business practice to produce cheaper per unit costs when more units are built. Additionally, there exists a "learning curve" where the employer becomes more efficient in producing new products as he builds more units. These basic business facts coupled with the government's practice of year by year contracting produces variability in the acquisition cost of each unit or ship built.

A year by year display of the acquisition costs for the

TABLE III

Acquisition Costs for SPRUANCE DD Class Ships

Year	Total in Class	Avg. 1984 Acq. Cost M(dlrs)	Total 1984 Acq. Cost M(dlrs)
1976	1	436.432	436.43
1977	5	361.865	1809.32
1978	10	317.150	3171.50
1979	14	299.539	4193.55
1980	20	285.003	5700.07
1981	29	272.658	7907.08
1982	30	272.505	8175.16
1983	30	272.505	8175.16

Spruance class ships is presented in Table III. This information was obtained from the data base used in this analysis. The data base will be explained in detail in Chapter II.

Utilizing forward differencing, which will be described in Chapter III, the four proportional growth rates for the Spruance class ships which will be studied in this analysis are displayed in Table IV . The information from Table III was utilized in the forward differencing technique to create

TABLE IV

Growth Rates for SPRUANCE Class Destroyers

Year	Units / Dollar	Std.Tons/ Dollar	Gen.Cap./ Dollar	Crew Size/ Dollar
1976	0.170857	0.170857	0.170857	0.170857
1977	0.123567	0.123567	0.123567	0.123567
1978	0.055528	0.055528	0.055528	0.055528
1979	0.048528	0.048528	0.048528	0.048528
1980	0.043317	0.043317	0.043317	0.043317
1981	0.000559	0.000559	0.000559	0.000559
1982	0.000000	0.000000	0.000000	0.000000

the growth rates in Table IV . It is important to note here that the forward differencing procedure utilizes the average acquisition cost of the ships of the class that are in commission that particular year. This can be seen by looking at the average acquisition cost in the years 1981 and 1982 in Table III . Since the average acquisition cost decreases only slightly from 272.658 million to 272.505 million dollars and the forward differencing technique is utilized, the growth rate for Units / Dollars(Million) in 1981 is only 0.000559. And, because all Spruance class ships have the same tonnage,crewsize, and electrical gener-

ating capacity, the four proportional growth rates in any year are equal. This is true since the only change is in cost. It is also of note that there was no change in 1982 in the growth rates of Spruance class ships as shown in Table IV . This is because no Spruance class ships were introduced or decommissioned in 1982 so there is consequently no change. Although Table IV is therefore not very complex ,it illustrates one of the effects that is changing the Fleet. Also,when the Spruance class data is to be grouped with type,major type, or the fleet, these growth rates are needed.

To show the learning curve effect on the Spruance class ship, a plot of one of the Spruance class growth rates against years, as formulated by the data base and the year to year forward differencing technique, is displayed in figure 1.3 . It should be noted that the other growth rate plots over time will be in exactly the same form as the Unit/Dollar growth rate which is shown.

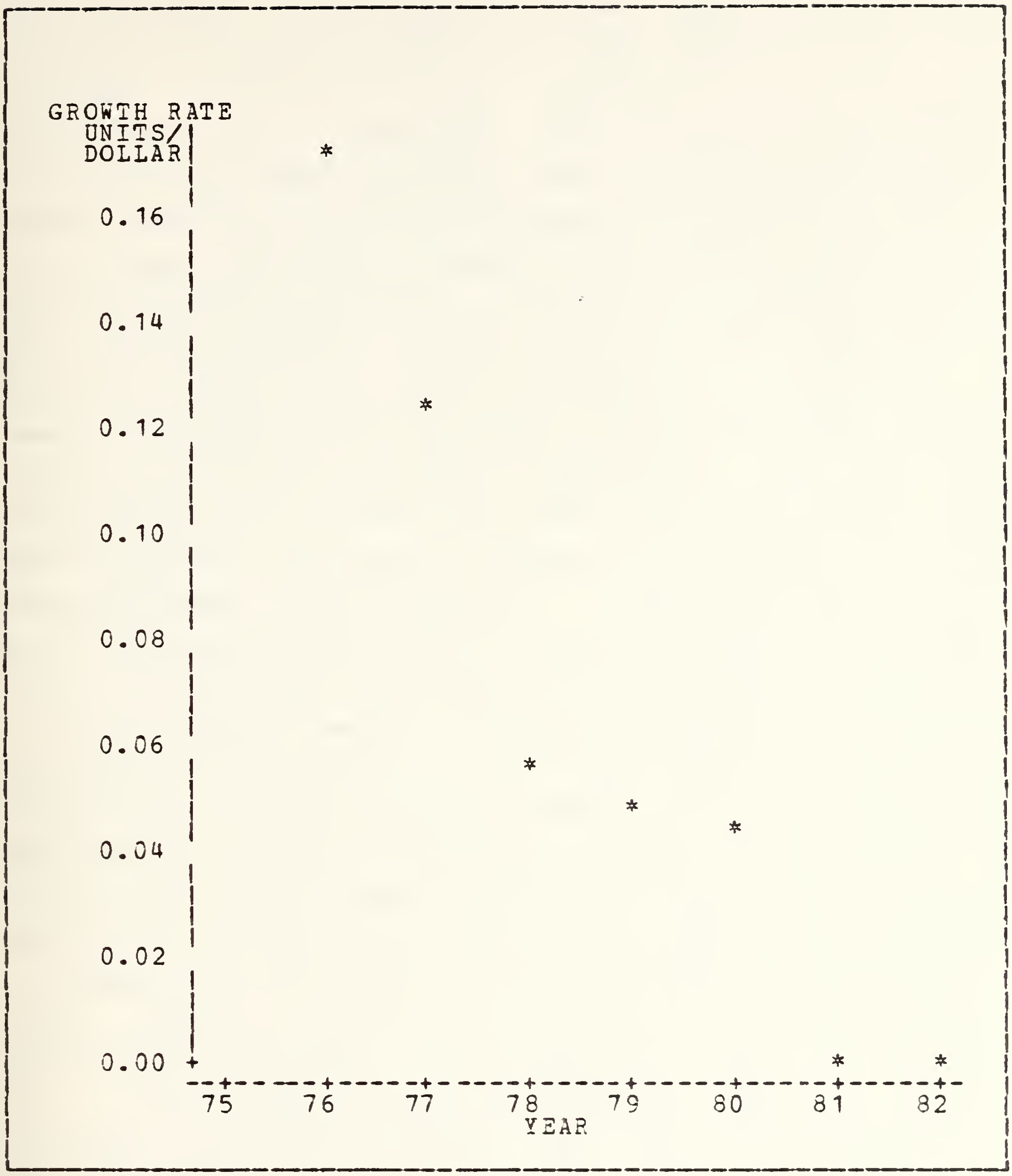

Figure 1.3 Unit/Dollar Growth Rate for SPRUANCE Class.

An interesting effect on the proportional growth rates occurs when the various homogeneous classes of ships are

aggregated with other classes to form the non-homogeneous categories of types of ships and major types of ships. As mentioned in the background section of this chapter, numerous World War II destroyer (DD) classes of ships were decommissioned during the late 1960's and early 1970's. The Sumner, Gearing, and Fletcher class destroyers all left the active fleet with some remaining as reserve units before being retired from the Navy. This exodus of ships, coupled with the introduction of the Spruance class can best be described visually with plots of number of units active or reserve, average standard tonnage, average crewsize, average generating capacity, average acquisition cost and total acquisition value of destroyer (DD) type ships against time. These plots are displayed in Figures 1.4 through 1.9 on the following pages of this section. A vertical line has been drawn through the year 1975 in all of the above plots indicating the time when the first of the Spruance class became an active fleet member. These visual plots display a consistent destroyer type force from 1962 to 1967. In Figure 1.4, there is a sharp drop in the total number of destroyers especially in the time period 1969 to 1973. In Figure 1.5, the average tonnage of a destroyer remained relatively the same until the Spruance class was introduced. In Figure 1.6, the older destroyers which were decommissioned caused a rise in the average destroyer crewsize before the introduction of the Spruance class. In Figure 1.7, it is evident that the Spruance class has greatly increased generating capacity over the other destroyers. And, in Figure 1.8, there was some increase in the average acquisition value of the destroyers before the Spruance class arrived. However, it is obvious that Spruance is much more expensive than the other destroyer type ships. Figure 1.9 ,in concert with Figure 1.4 , shows an interesting result. With one-fourth of the number of destroyer ships,

the Destroyer type in 1982 has more than one-half of the cumulative acquisition asset value than it had in the early 1960's.

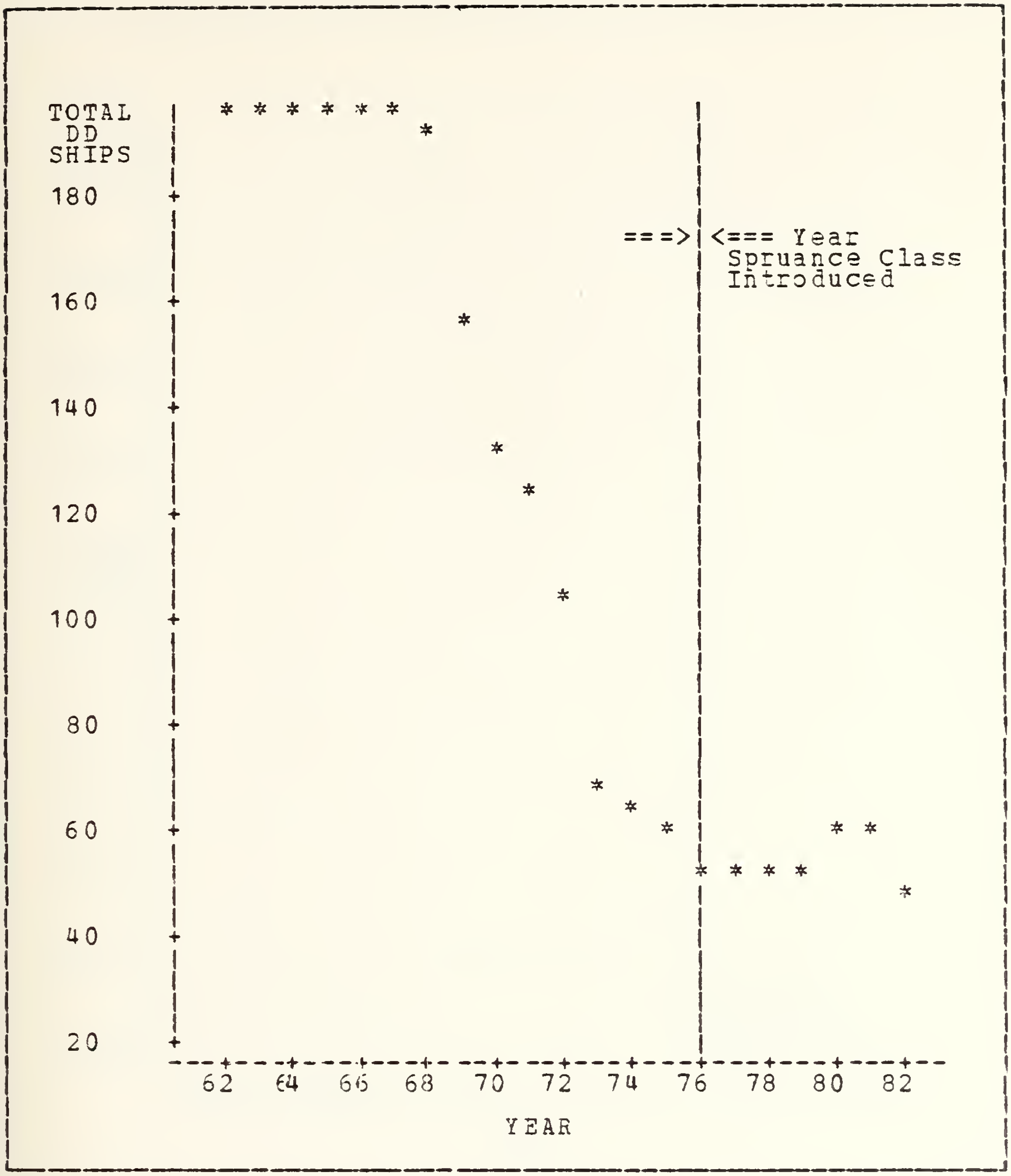

Figure 1.4 Total Number of DD Type Ships during 1962-1982.

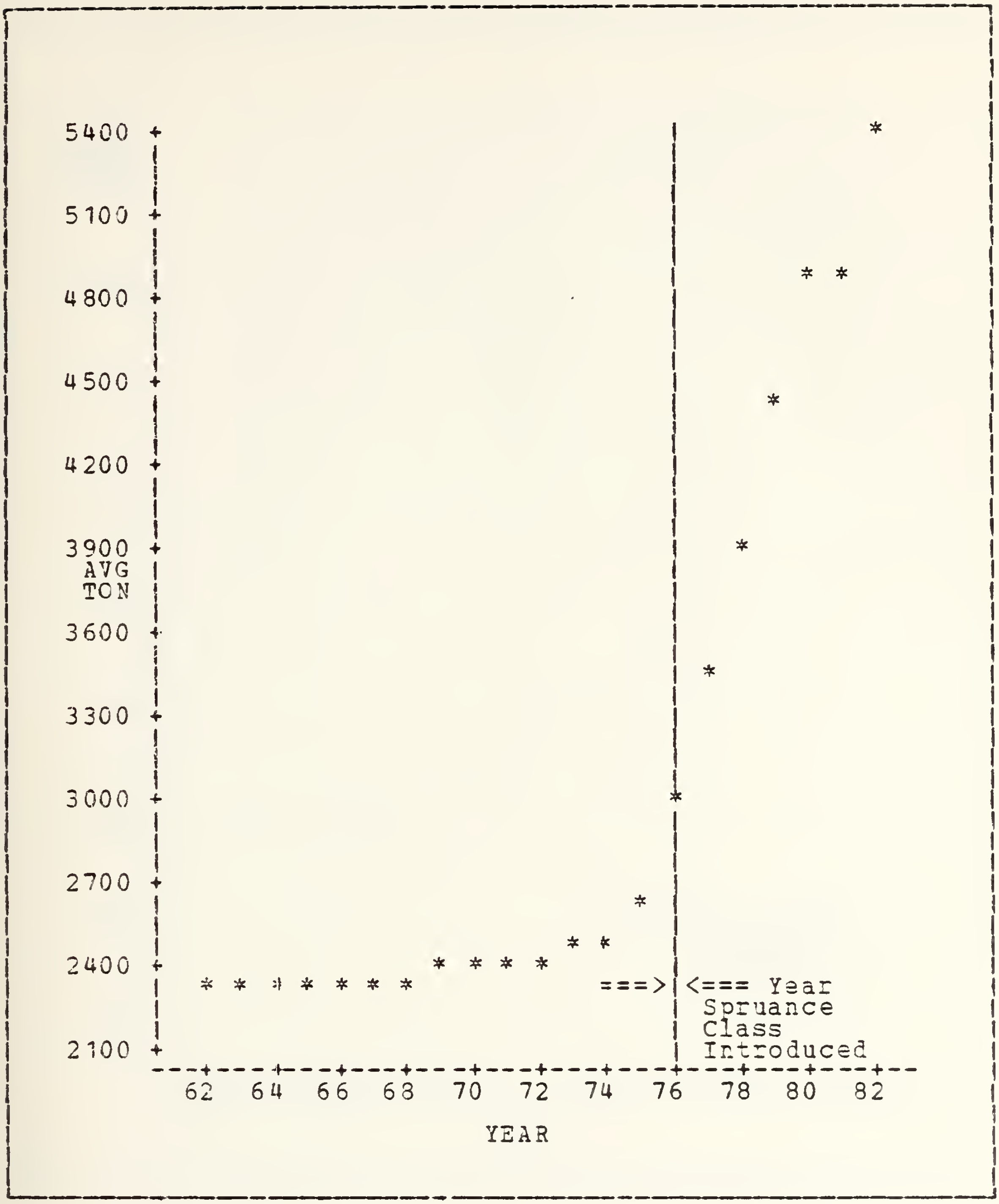

Figure 1.5 Average Tonnage of DD Type Ships 1962-1982.

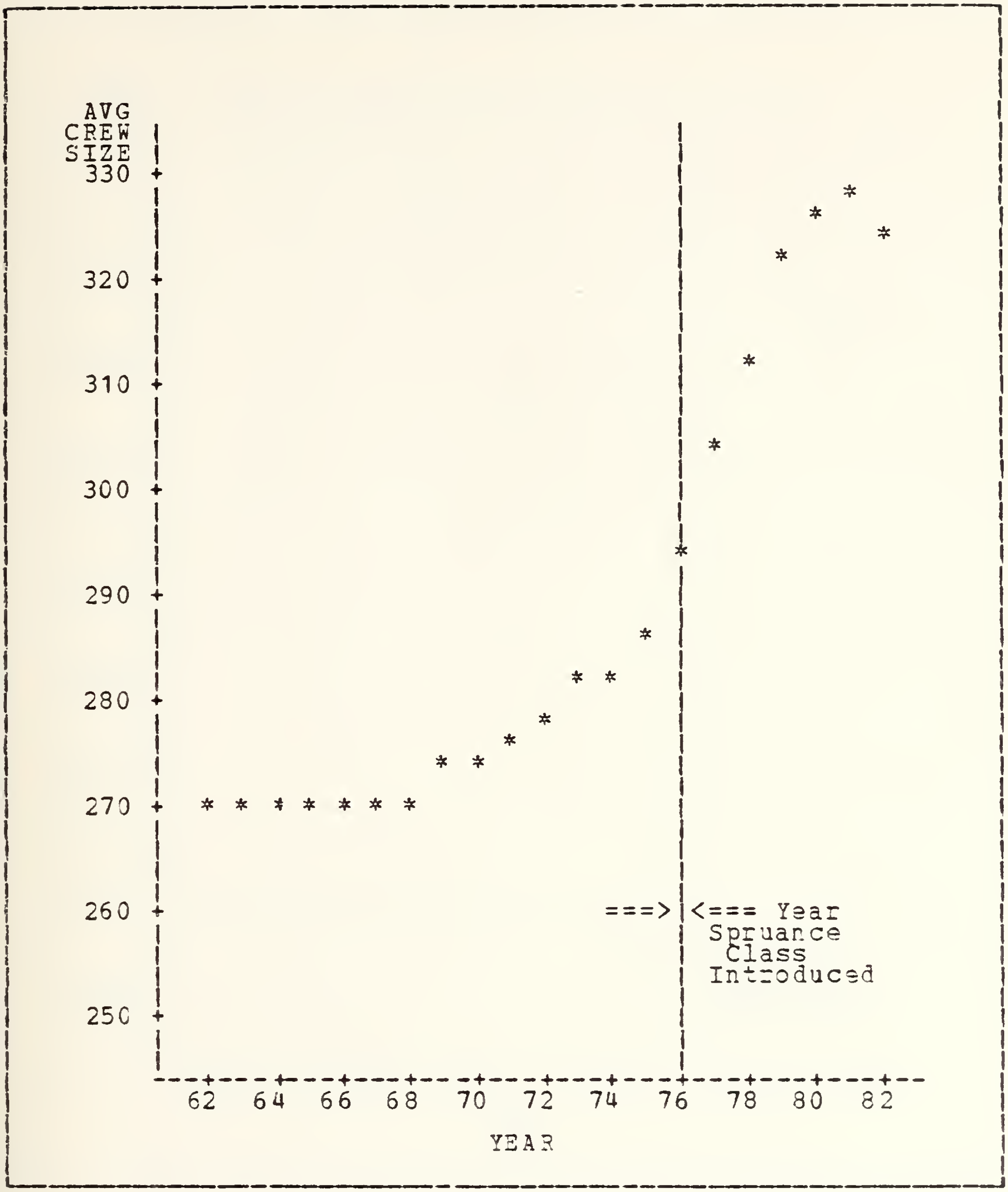

Figure 1.6 Average Crew Size of DD Type Ships 1962-1982.

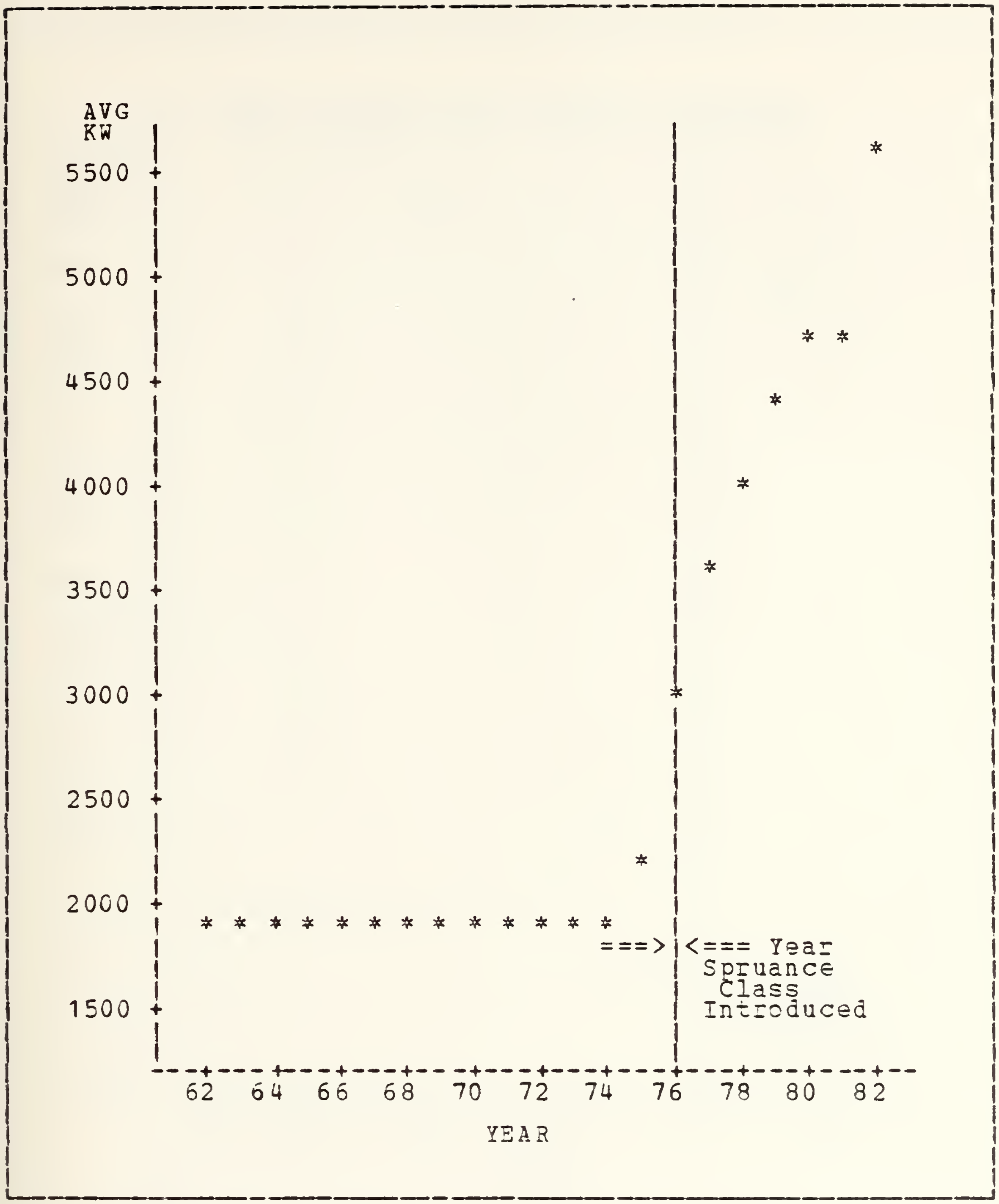

Figure 1.7 Avg. Generating Capacity DD Ships 1962-1982.

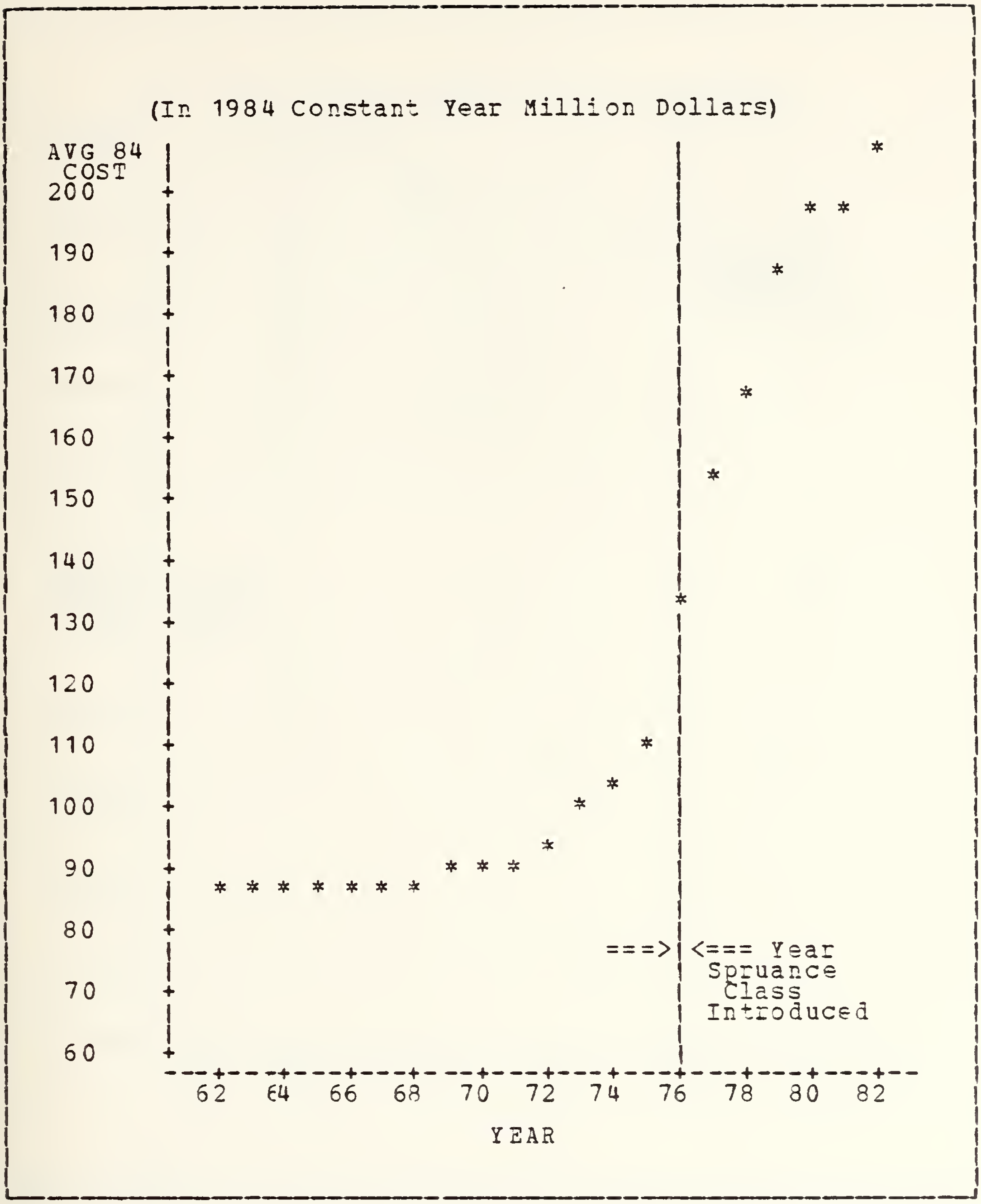

Figure 1.8 Avg. Acq. Cost DD Type Ships 1962-1982.

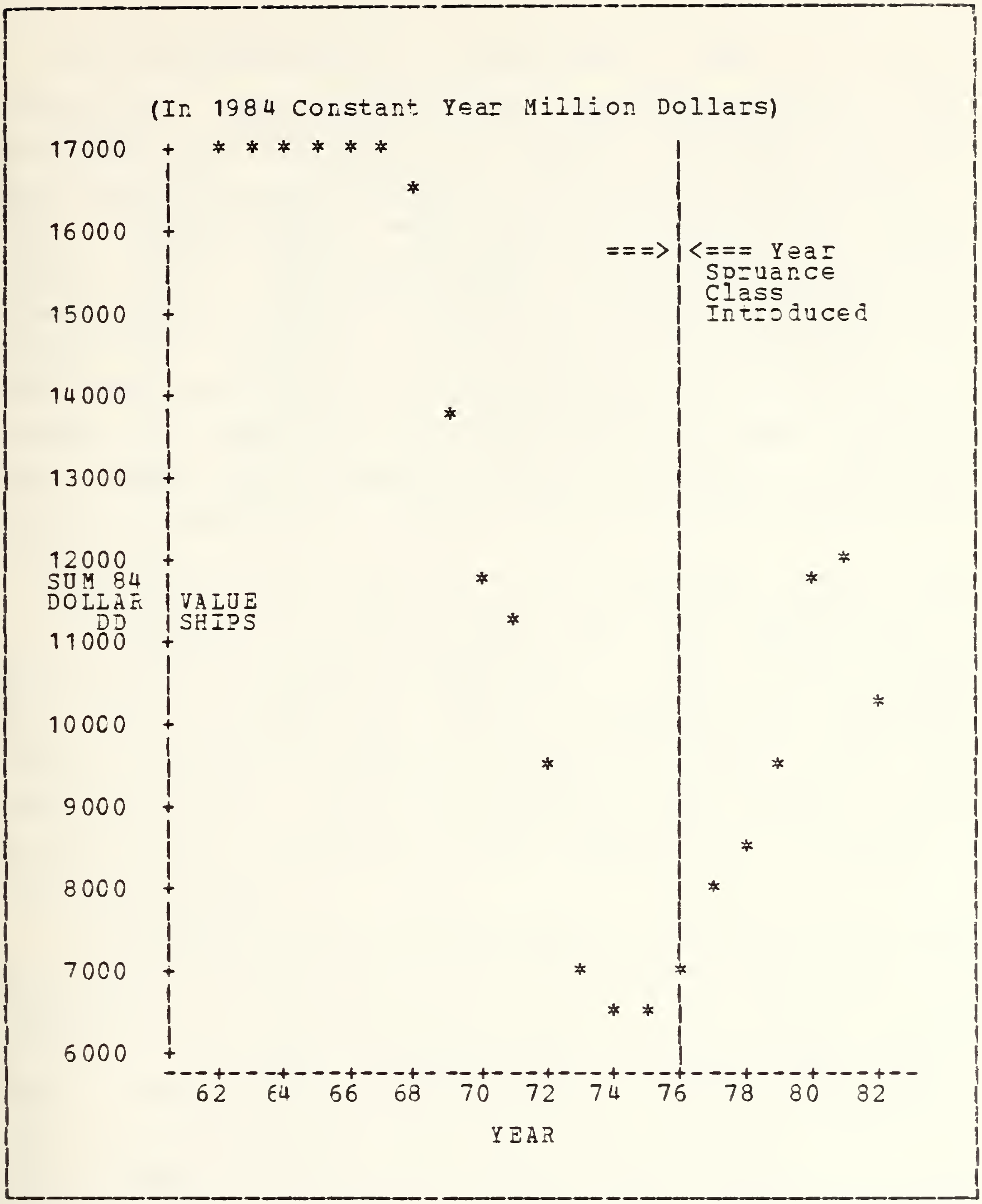

Figure 1.9 Total Acq. Value of DD Type Ships 1962-1982.

When decommissioning and retirement began to occur in the smaller, older World War II class destroyers in 1969, its effect shows changes in the average destroyer type ship long before the introduction of the Spruance class ship in 1976. These effects were shown in Figure 1.4 through Figure 1.9 . The evolutionary numerical tabulation of these changes and the resultant "average" destroyer are displayed in Table V . It is noteworthy that all of the "average" destroyer (DD) statistics increase over time. A decrease in numerical value followed by a short peak and then another fall occurs to both the number of ships and the total acquisition value of destroyer type ships listed in Table V .

And finally, the effect on the proportional growth rates to be studied in this analysis for the sample case of destroyers is displayed in Table VI . Thus, it is evident that when utilizing the forward differencing technique, there are multiple effects occuring to a type of ship that occur over time . Both introduction of new classes of ship and exit from the fleet of older classes have an impact on this methodology.

A digression into interpretation of some of the entries and trends in Table VI and its relationship with Table V is important. It is noted that there were no new ships introduced or old ships decommissioned in the early 1960's. Thus, there are zero growth rates in all four cost categories. In the late 60's and early 70's, there are changes in the "average" destroyer statistics shown in Table V . This is also evident in all four growth rates in Table VI showing negative values between 1968 and 1975. Also, it is important to note in Table VI the changes in growth rates that occur before and after the Spruance class is introduced. In the standard tons per dollar (asset value) growth rate, the Spruance class introduction actually causes a shift from

TABLE V

Average Statistics for DD Type Ships During 1962-1983

Year	Number of Ships	Avg Tons	Avg Crew Size	Avg Gen. Capacity	Avg 84 Cost in M(dlrs)	Total Value M(dlrs)
63	197	2329.44	270.396	1933.33	86.157	16972.9
64	197	2329.44	270.396	1933.33	86.157	16972.9
65	197	2329.44	270.396	1933.33	86.157	16972.9
66	197	2329.44	270.396	1933.33	86.157	16972.9
67	197	2329.44	270.396	1933.33	86.157	16972.9
68	197	2329.44	270.396	1933.33	86.157	16972.9
69	192	2333.98	270.740	1933.33	86.355	16580.2
70	155	2381.94	274.110	1933.33	88.342	13693.0
71	131	2398.09	274.786	1933.33	90.102	11803.3
72	124	2412.30	275.702	1933.33	90.800	11259.3
73	102	2434.56	277.716	1933.33	93.372	9524.0
74	69	2497.83	281.449	1933.33	100.389	6926.8
75	64	2507.03	282.641	1933.33	101.988	6527.3
		Spruance Class	Introduction			
76	60	2593.75	285.367	2187.50	109.263	6555.8
77	53	2583.96	294.906	2950.00	132.844	7040.7
78	52	3463.46	304.058	3560.00	152.204	7914.6
79	51	3866.18	311.824	4000.00	167.311	8532.9
80	51	4439.71	322.294	4352.94	187.200	9547.2
81	60	4868.75	326.900	4697.67	195.904	11754.2
82	61	4908.61	327.328	4727.27	197.087	12022.3
83	49	5132.65	323.980	5636.36	206.792	10132.8

TABLE VI

Cost Growth Rates for DD Type Ships 1962-1982

Year	Units / Dollar	Std.Tons/ Dollar	Gen.Cap./ Dollar	Crew Size/ Dollar
1962	0.00000	0.000000	0.000000	0.00000
1963	0.00000	0.000000	0.000000	0.00000
1964	0.00000	0.000000	0.000000	0.00000
1965	0.00000	0.000000	0.000000	0.00000
1966	0.00000	0.000000	0.000000	0.00000
1967	0.00000	0.000000	0.000000	0.00000
1968	-0.00230	-0.000350	-0.002300	-0.00103
1969	-0.02301	-0.002415	-0.023009	-0.01043
1970	-0.01992	-0.013044	-0.019916	-0.01740
1971	-0.00776	-0.001823	-0.007758	-0.00441
1972	-0.02832	-0.018919	-0.028321	-0.02086
1973	-0.07515	-0.047916	-0.075148	-0.06089
1974	-0.01593	-0.012205	-0.015935	-0.01165
1975	-0.07133	-0.035513	0.053147	-0.06110
Spruance Class Introduction				
1976	-0.21581	-0.056820	0.098445	-0.17648
1977	-0.14574	0.012886	0.050585	-0.11125
1978	-0.09926	0.015245	0.021661	-0.07188
1979	-0.11888	0.025663	-0.028156	-0.08253
1980	-0.04649	0.045726	0.030303	-0.03175
1981	-0.00604	0.002129	0.000259	-0.00472
1982	-0.04924	0.051970	0.119991	-0.06009

negative growth to positive growth. Although not as pronounced, the same effect occurs with the generating

capacity per dollar growth rate. These trend relationships are not difficult to observe at the class and type level. However, when aggregation into larger groups occurs, these trends become opaque and hard to detect.

There is also evident in these displays a dependence between years as one observes the evolutionary process of the Navy as it modernizes itself. This dependence between years cannot be avoided as one observes the fleet changing over time. The Fleet can only be changed so fast. Thus, the dependence between years becomes a critical difference and a critical assumption in the proposed methods of aggregating the various classes, types and major types of ships that compose the Naval force of the United States Navy.

II. DATA BASE

A. DATA BASE DESCRIPTION AND MEASUREMENT

In order to forecast future trends, it is necessary to have data available and make certain assumptions. Makridakis and Wheelwright [Ref. 6] stated quantitative forecasting can be applied when three conditions exist:

1. There is information about the past.
2. This information can be quantified in the form of data.
3. It can be assumed that the pattern of the past will continue in the future.

This last condition is known as the <u>assumption of constancy</u> and it is an underlying premise of all quantitative and many technological forecasting methods, no matter how sophisticated they may be. This assumption of constancy must be kept in mind during the methodology discussions of growth rates to be presented in Chapter III.

The analysis in this thesis is based on data derived from U.S. Navy sources, budget documents, and data made available from the Program in Logistics, Navy Resource Dynamics, George Washington University. The majority of the data base was obtained from the Navy Resource Dynamics Model researchers by computer tapes sent through the mail. Since the main frame computers at George Washington University and the Naval Postgraduate School are compatable International Business Machine computers, it was possible to directly transfer the data base by tape for immediate access. Both facilities maintain the Statistical Analysis System (SAS) issued by the SAS Institute. These two compatabilities were invaluable in reducing data base confirmation, loading times and data base manipulation.

The data base utilized by this analysis has the information listed in Table VII and is self-explanatory with one exception. The acquisition cost (AQCOST) is supposedly the government's "actual" acquisition value of the ship including government furnished equipment (GFE) and government furnished material (GFM). The data base lists over 1500 ships that have been commissioned in the U.S. Navy, Naval Reserve Force (NRF) and Military Sealift Command (USNS).

TABLE VII

Historical Ship Data Base

Category	Description
NAME	Name of Ship
HULL	Hull Number of Ship
CLASS	Ship Type (example: DD for destroyer)
CLSNAME	Name of Ship's Class
LNCHYR	Year in which ship was launched
AQCOST	Best estimate of the acquisition cost of that specific ship (ACSTYR Current $) (No conversions/modifications included)
ACSTYR	Year in which acquisition of the ship occurred
RETYR	Year in which the ship was retired (if applicable)
TONNAGE	Standard tonnage of the ship
CREW	Size of the crew: Ship's manning document (SMD) figures
GENCAP	Electrical generating capacity in kilowatts
DCODE	Ship's major type (example: amphibious ships
AQCST84	Acquisition cost in constant 1984 dollars

The Resource Dynamics data base contains additional information not utilized in this thesis. This includes major modification cost information. In analyzing the total asset value of the force, that particular type of costing information can be critical. However, it was not essential for the study of acquisition cost growth rates. It must be recognized that a significant portion of the Navy's overall budget is utilized for service life extention programs (SLEP) and major modifications to older units as alternatives to procurring new ships. Its impact is not felt on acquisition costs for new platforms . It is felt on the number of new units that can be purchased.

B. DATA BASE LIMITATIONS

It is necessary to make some assumptions in order to obtain the aggregated growth rates of the Fleet. Some degradation in transformation occurs when transferring from individual ship data to the aggregated fleet level. It is critical to explain some of the idiosyncracies of the data base and its applicability to the forthcoming methods described in Chapter III. For instance, as was presented in Chapter II while discussing the Spruance class destroyer, it was approximately two years from launching to the actual commissioning date of USS Spruance (DD963). In the forward differencing technique used in Chapter III, the figure of two years is utilized to estimate the ships who were commissioned in a particular year. Thus, in the data base, commission year equals launch year plus two. Several ships were commissioned in less time and several ships were commissisoned over a longer period of time, not only for the Spruance class but other classes and types of ships.

Another self confessed limitation in the forthcoming forward differencing methodology discussed in Chapter III is the inclusion of the inactive units which become recommissioned after a certain period of inactivition. For instance, all four of the Iowa class battleships are included in the commissioned (active or reserve) forward differencing computations during the entire period of 1962-1982. An exception exists for USS New Jersey which was retired in the data base in 1970. USS New Jersey was brought out of retirement for both the Korean conflict and the Vietnam War and was recently recommissioned for the fourth time. Thus, the battleships are a unique class of ship. They do not follow the normal progression of commissioning,active service, perhaps NRF duty and then retirement. It must be emphasized that this data anomaly does not affect the regression methodology, only the forward differencing methodology.

An additional critique of the data base is that not all ships have electrical generating capacity displayed. The data base is accurate with the recent classes and types of ships. However, the data base is missing for some of the older ships. As an example, when observing the commissioned ships in 1962, a total of 852 ships are left in the data base when USNS ships and units under 300 tons (Patrol Combatants and Patrol Hydrofoils) are deleted. Only 181 of these ships have generating power data available. The other categories are more complete with 823 units having tonnage information in 1962, 796 having crew complement information and all 852 units having costing information. These gaps are all closed progressively over the years, so that, by 1983, a total of 518 ships are active/reserve with all 518 having tonnage and costing information, 516 having crew size information and 494 having electrical generating capacity information. This anomoly again directly affects the

forward differencing methodology and not the regression technique.

C. STATISTICAL ANALYSIS SYSTEM UTILIZATION

A desirable objective of any analysis that is conducted is to make the final product and its procedures reproducible. All of the analysis for this thesis was conducted utilizing the Statistical Analysis System, a product of the SAS Institute. The Statistical Analysis System is an outstanding user oriented tool. Once its basic features and nomenclature have been mastered, SAS provides excellent results. Not only is the Stastical Analysis System user friendly for the operator, especially in the handling of error messages, it is also computer efficient in its utilization of CPU time. The SAS User's Guide, [Ref. 7], was most helpful in displaying the systems ability to create, manipulate and sort data sets. Additionally, the procedure steps were not only straightforward, but were also well documented on their utilization, limitations and special considerations for usage. Several of the major SAS programs utilized in this analysis will be displayed in appendices.

There did exist one imperfection in this analysis while using the SAS computing capability. In order to perform the Regression Method discussed in Chapter III, the slope of the time-series regression line, the coefficient estimate of time, could not automatically be listed as an output from the GLM (General Linear regression Models) procedure in [Ref. 7]. This slope is to be combined with other slopes in forming the aggregate acquisition cost growth rates for the entire U.S. Navy.It is understood by this author that this capability will be added to SAS in the future. This will reduce calculating times significantly.

D. ELIMINATING INFLATION EFFECTS

In order to obtain "real" growth rates, it is imperative that the effects of inflation be eliminated from the data. Otherwise, inflationary effects can intertwine and distort the quantification results. The Deflator Scale listed in Table VIII was utilized in this study to bring the acquisition cost (AQCOST) of each ship in the data base to a "constant" 1984 dollar value. By dividing the acquisition cost (AQCOST) by the deflator of the year in which the ship was acquired (ACSTYR), all platform acquisition costs were elevated to 1984 "constant" dollar values and stored as AQCST84 in the SAS data base. The deflator scale listed in Table VIII was obtained from the Chief of Naval Operations (OPNAV 96-D) Staff.

It must be recognized that deflator scales can not be perfectly absolute and different deflator scales exist for the same "basket of goods". In order to reduce the computing iterations, only the deflators listed in Table VIII were utilized in this study.

TABLE VIII

Navy Ship Construction (SCN) Deflator Scale

Year	Deflator	Year	Deflator	Year	Deflator
39	0.0865	55	0.1440	70	0.2535
40	0.08714	56	0.1499	71	0.2763
41	0.0935	57	0.1613	72	0.2965
42	0.10113	58	0.1632	73	0.3181
43	0.10495	59	0.1670	74	0.3674
44	0.10686	60	0.1657	75	0.4273
45	0.10813	61	0.1690	76	0.4944
46	0.11387	62	0.1670	77	0.5345
47	0.1270	63	0.1675	78	0.5793
48	0.1275	64	0.1682	79	0.6361
49	0.1280	65	0.1746	80	0.7004
50	0.1285	66	0.1846	81	0.7837
51	0.1408	67	0.1967	82	0.8590
52	0.1359	68	0.2105	83	0.9320
53	0.1378	69	0.2343	84	1.0000
54	0.1351				

III. ANALYSIS / METHODOLOGY

A. RESULTS

It is appropriate to overview the preferred results of the analysis before delving into the exact equations and methodology of producing each of the three method alternatives. The four proportional acquisition cost growth rates studied are unit per dollar, tonnage per dollar, generating capacity per dollar and crewmember per dollar. These growth rates will be displayed in the tabulated results as GRU/C, GRT/C, GRKW/C and GRP/C respectively. The three methods of aggregating the cost growth rates are as follows:

1. Method A utilizes a linear least-squares time-series regression technique on major types of ships and then aggregates the data into the total fleet.

2. Method B conducts a moving aggregation of cost growth rates by keeping track of all the commissioned active and reserve ships in a particular year, compares yearly totals by class and type of ship utilizing a forward differencing function described below and then aggregates the results;

3. Method C is a combination of Method A and Method B. It utilizes the forward differencing function technique on the classes of ships for the years in which they are active or reserve.

All three historical growth rate computations are analyzed using four different weights, namely:

1. Each class of ship weighted equally;

2. Each ship weighted equally;

3. Each class weighted by the average acquisition value of that class;and

4. Each ship being weighted by its own acquisition cost. These weighting factors will be displayed in the tabulated results as WT1,WT2,WT3, and WT4 respectively. The choice of which weighting factor to use is not clear. Therefore,an average, denoted by AVG, of all four weighting factors will also be presented in the tabulated results.

The results using time-series regression are shown in Table IX . The incorporation of years 1962 to 1983 were

TABLE IX

Method A Cost Growth Rates Results

Time-Series Regression Technique
(During the Years 1962-1983)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1	-2.1899	0.211547	3.17215	-0.14756
WT2	-2.1121	0.613916	2.20314	-0.03784
WT3	-0.80782	1.37164	2.33942	0.338946
WT4	-1.5056	1.1344	2.0827	0.061241
AVG	-1.654	0.833	2.449	0.0537

chosen to reflect the majority of classes of ships which are presently existing in the active U.S. Navy as it exists today. Additionally these years are coincident with the same beginning year as Dr. Clark's previous work in [Ref. 2]. Method A thus does not include ships commissioned before 1962 in its computations. Thirteen major categories of ship types were selected as the preferred grouping for regression analysis. They are displayed in Table X . These major types of ships were chosen to reflect as homogeneous a grouping of ship types as possible. The breakout among

TABLE X

Preferred Grouping of Ships for Method A

Major Types	Type of Ships Included
Strategic Submarines	SSBN
Nuclear Attack Submarines	SSN
Conventional Submarines	AGSS, SS
Nuclear Cruisers	CGN
Large Surface Combatants	AGMR,BB,CA,CC,CG,CLG,DDG (AAW oriented)
Smaller Surface Combatants	DD,DE,DER,FF,FFG (ASW oriented)
Amphibious	APA,APB,APD,AVT,LCC,LFR LHA,LKA,LPA,LPD
Minesweeps	MCM,MCS,MCSO,MSH,MSO
Auxiliary	AE,AF,AFS,AG's,AH,AK,AKL ANL,AO,AOE,AOG,AR's
Tenders	AD,AS
Conventional Aircraft Carriers	CV,CVS
Nuclear Aircraft Carriers	CVN

surface combatants was done to reflect the high - low mix of ships and their principal mission in the Navy. Although surface combatants pride themselves in being multi-mission capable platforms, it was necessary to reduce the total number of ships in that category and it was felt this was a reasonable subdivision of those ships. The alternative grouping of major types of ships, the changing of the period of years studied and the regression statistics will be presented in detailed in Section B of this chapter.

The results of Method B using the forward differencing function technique utilizes only a five year time period, namely 1978 to 1982. The forward differencing function technique will be discussed in Section C of this chapter. The ships are aggregated by class or by type in each year before being aggregated into the whole Navy. For this reason, both class and type results are displayed in Table

XI for each weighting factor and are both utilized when all the weighting factors are averaged.

Over a significant period of time and with a homogeneous type of ship the results of Method A and Method B tend to

TABLE XI

Method B Cost Growth Rates Results

Forward Differencing Technique
of Class(C) and Type(T)
(During the Years 1978-1982)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1C	-3.0414	-0.8234	-0.61234	-3.9542
WT1T	-1.0285	-1.2711	0.717061	-1.9624
WT2C	-0.30492	-0.0086021	0.199299	-0.48512
WT2T	-1.3888	0.15829	1.30677	-1.5183
WT3C	-3.5695	-1.261	-0.47483	-4.7931
WT3T	-1.0678	-1.3383	0.753308	-2.0511
WT4C	-0.93171	-0.033344	0.0713668	-1.1987
WT4T	-1.1813	0.257659	1.11948	-1.3014
Avg	-1.564	-0.540	0.385	-2.158

converge and approach one another in value. How to best capture the convergence and try to represent a heterogeneous body of ships in the aggregate is the art of this study. As described in Chapter I, there existed an influence on the Navy's basic parameter characteristics as the World War II ships were being decommissioned in the late 1960's and early 1970's. Since the years chosen for Method A was 1962 to 1983 and Method A only studied new platforms entering the Fleet, it was essentially describing the newer active ships. By only utilizing the last five years in Method B, it can eliminate the decommissionings conducted in the late

60's/early 70's and in that way captures the essence of recent growth. The results for a twenty one year (1962-1982) period and a ten year (1973 to 1982) forward differencing period are tabulated in Section C of this chapter.

The results of Method C, using the differencing function technique on the classes of ships introduced into the fleet

TABLE XII

Method C Cost Growth Rates Results

Forward Differencing Technique
of Class(C) and Type(T)
(During the Years 1962-1982)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1C	-3.8004	-1.1642	-1.3065	-2.4712
WT1T	-4.2214	-1.9132	-2.2334	-1.643
WT2C*	-4.6387	-1.9303	-0.73794	-1.9795
WT2T*	-3.8588	-2.4647	-1.4817	-2.0533
WT3C	-5.5267	-1.974	-1.4616	-4.1191
WT3T	-5.2307	-1.8146	-1.5909	-3.3406
WT4C*	-7.5915	-3.1242	-1.2552	-3.1034
WT4T*	-3.3438	-1.6638	-0.88745	-1.7277
Avg	-4.776	-2.006	-1.369	-2.555

since 1962, are presented in Table XII . This methodology of differencing on the lead ship of each class as it is introduced into the fleet is not recommended for utilization for reasons which will be dicussed below. It was not possible to program weights WT2 and WT4 where, respectively, each ship and its value is counted equally. WT2* in Table XII means that each class is weighted equally for the years in which the class is commissioned or reserve since 1962.

WT4* in Table XII means that each class is weighted by its average acquisition value for the years in which the class is commissioned. As performed in Method B, the ships are aggregated by class or by type. Both class and type results are displayed in Table XII for each weighting factor and are indicated by a "C" and "T" respectively. Again, this method is not recommended for utilization. However, this method was attempted as an alternative to Methods A and B as a possible compromise between their faults and weaknesses.

B. METHOD A (TIME-SERIES REGRESSION TECHNIQUE)

1. Theory Description

Before describing in detail the various methodologies, it is important to define the stylized facts of growth. As described in [Ref. 7, p.369], Nicholas Kaldor in 1958 utilized the long term relationships that seem to appear consistent over time as stylized facts, or rough empirical observations in economic models. These stylized facts are utilized in growth models that tie these stylized facts together. Often, these long term relationships take the form of ratios. In this analysis, the ratios studied are units per dollar, tonnage per dollar, generating capacity per dollar and crewmember per dollar. The basic equation of growth rate (GR) for an item X is:

$$GR(X) = (dX / dt) / X \qquad \text{(eqn 3.1)}$$

It should be noted that whenever the growth rates of ratios are taken (say cost per ton), that over any increasing period of time, the negative value is the reciprocal of the ratio (ton per dollar). Thus, the growth rates described in this chapter also describe cost per unit, cost per ton, cost per generating capacity and cost per crewmember. And, a negative growth rate of a ratio over time is also a positive

growth rate of its reciprocal and has the same magnitude. For example, in Chapter I Table IV, the Spruance class growth rate for tons per million dollars in 1981 was 0.000559 when the forward differencing technique was used. The implied growth rate for cost (million dollars) per ton in 1981 for Spruance class destroyers is -0.000559.

As described in [Ref. 8], the simplest deterministic time-series model is the linear trend model. Since the data base on the ships consists of discrete observations made at yearly intervals, the long-run growth pattern of the time series can be described by the linear trend model. The time series is denoted by Y(t). Despite short-run up-and-down movements, it is possible that Y(t) might exhibit a clear-cut upward trend. For example from the data base, there are four nuclear cruiser (CGN) classes introduced in the time frame 1962 to 1983. The names of the classes of CGNs are Truxton,Bainbridge,California and Virginia. Figure 3.1 shows a plot of the predicted values (YHAT) versus the actual tonnage per dollar value for nuclear cruisers. The predicted values were determined by the generalized linear regression model (GLM) SAS procedure. The COMMYR is the year when the lead ship of the class is introduced to the fleet. The value of each ship class is the average acquisition cost of the ships in that class. As described in [Ref. 9], the actual data which indicated a growth in the ratio of tonnage per dollar value can be compared with the regression model's predicted values, which also shows similiar growth.

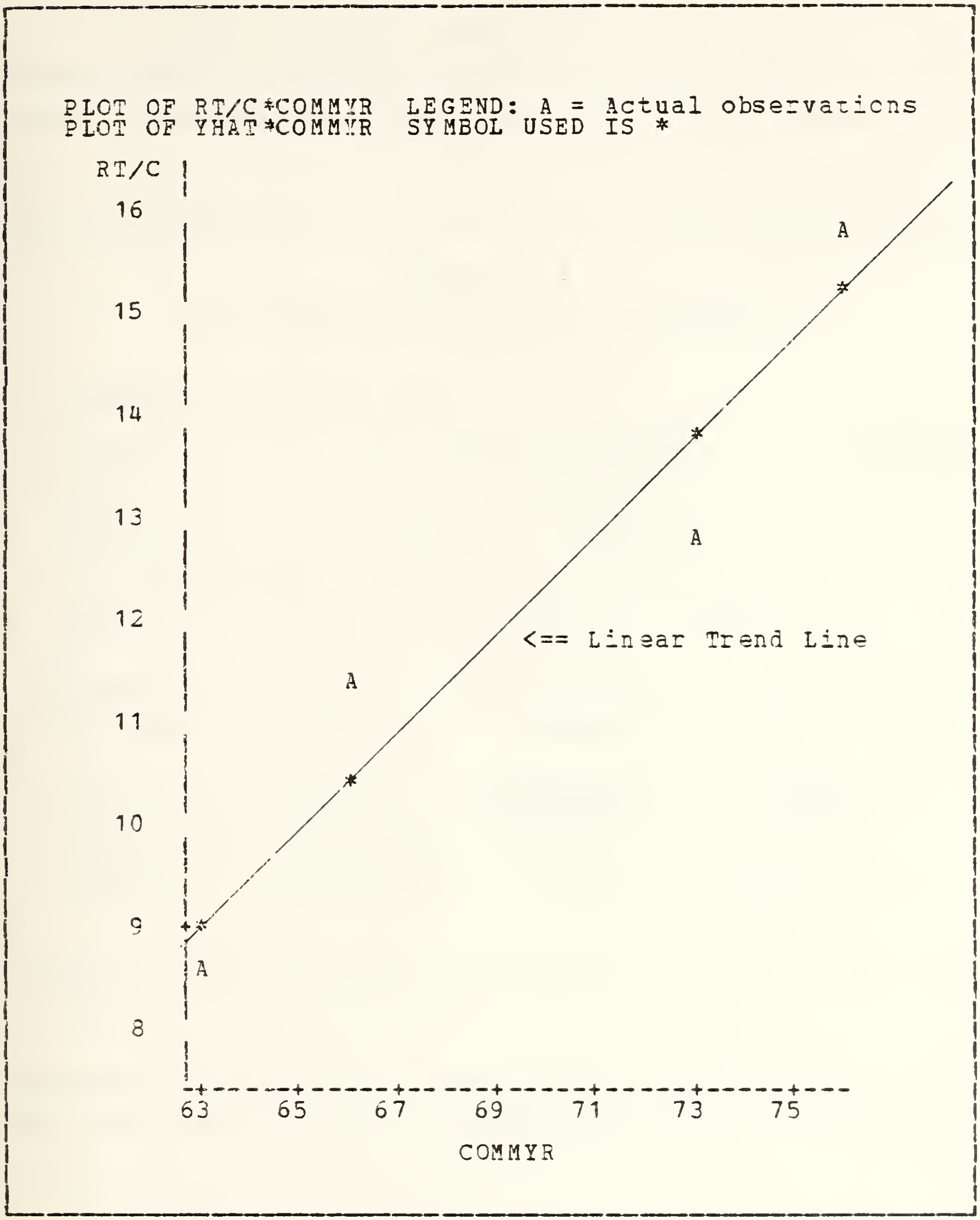

Figure 3.1 Predicted vs. Actual Ratio (Tons/Dollar) for CGNs.

In this example, the analysis of variance table, miscellaneous statistics and the parameter estimates of the linear regression trend line from the GLM SAS procedure are

TABLE XIII

SAS General Linear Models Procedure

DEPENDENT VARIABLE: RTC

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	1	24.85629815	24.85629815
ERROR	2	2.14438056	1.07219028
CORRECTED TOTAL	3	27.00067871	

MODEL F = 23.18 PR > F = 0.0405

R-SQUARE	C.V.	STD DEV	RTC MEAN
0.920580	8.5370	1.03546621	12.12909541

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	STD ERROR OF ESTIMATE
INTERCEPT	-21.05956936	-3.05	6.91240361
COMMYR	0.47753474	4.81	0.09917968

provided in Table XIII . From the GLM output, Table XIII, the linear equation for the time series, Y(t) is as follows:

$$Y(t) = -21.06 + 0.4775 * (t) \qquad \text{(eqn 3.2)}$$

with: t expressed in two digit years (ex. 67,68, etc.) Thus, the value of the ratio of tonnage per dollar value in year (t+1) will be 0.4775 units higher than the previous

value.The other statistics on Table XIII , especially R-square which is equal to 0.9206, indicate that this is a reasonable model to estimate the slope (dX/dt) required for the basic equation of growth rate in equation (3.1). Additionally,the Durbin - Watson test for autocorrelation was performed using the SAS Procedure SYSREG. In the majority of cases,the null hypothesis of positive or

TABLE XIV

SAS General Linear Models Procedure

DEPENDENT VARIABLE: RTC
FREQUENCY: NCLASS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	1	46.07379821	46.07379821
ERROR	6	3.50347787	0.58391298
CORRECTED TOTAL	7	49.57727608	

MODEL F = 78.91 PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	RTC MEAN
0.929333	5.6310	0.76414199	13.57019066

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	STD ERROR OF ESTIMATE
INTERCEPT	-22.85728541	-5.56	4.10976086
COMMYR	0.50331573	8.88	0.05666143

negative correlation was rejected. Again, this statistical check indicated that the time-series regression technique is reasonable for estimating the slope.

When the growth rate is weighted by the number of ships in each class (i.e. each ship is weighted equally), the trend line changes. In our example of the ratio of tonnage to dollar value, there will be four more observations in the model. There are two California class CGNs and four Virginia class CGNs in the data base. Truxton and Bainbridge only have one ship in their respective classes. A trend line regression was run on the SAS GLM procedure with each ship counting equally and the results are shown on Table XIV . It is noted that the slope changes to 0.5033 and the R-square improved slightly to 0.929 when each ship is counted as shown on Table XIV . It is important to notice that this individual trend line result will be combined with other major types to form the aggregate fleet trend in growth.

2. SAS Steps

The actual procedural steps using SAS to obtain the cost growth rates for the entire Navy by Method A follow:

1. Starting with the entire data base of 1505 individual ships, USNS and ships with tonnage less than 300 are deleted.
2. Commissioned year is assumed to be launch year plus two.
3. The commissioning years of 1962 to 1983 are retained. The other units with commissioning outside of these dates are deleted. (By this methodology there exist a total of 57 new classes of ships introduced into the Navy since 1962.)
4. The number of ships in the class is obtained and is denoted by NCLASS. Also, the average acquisition value of a ship class is determined and is denoted by MAQCST84.

5. All units are deleted, except for the lead ship in each class. Its acquisition cost is replaced with the average cost of its class (MAQCST84).
6. For the lead ships of each class with its revised cost (MAQCST84), the desired ratios are taken. (Example: ratio of tonnage/dollar = RT/C = tonnage/MAQCST84) The other ratios are RU/C, RP/C and RKW/C.
7. The lead ships are sorted by the major types listed in Table X then:
   a) The average value of all above ratios for the ships in each major type are computed.
   b) Each major type has the GLM SAS procedure run on ratio versus commissioned year (COMMYR). As seen in the nuclear cruiser example, the slope of the regression trend line is the output.
8. The proportional growth rates are formed by dividing the slope by the average value of the ratio to create the growth ratios, namely: GRU/C, GRT/C, GRKW/C and GRP/C.

3. Weighting Factors

Once the four growth rates have been formed, the four weighting processes begin.

Weight one (WT1) is created by summing the total of all thirteen major types growth rates times the number of classes in the major type. This quantity is then divided by the total number of classes introduced between 1962 and 1983 (= 57).

Weight Three (WT3) is created by summing the total of all thirteen major type's growth rates times the sum of the average cost (MAQCST84) of each class in that major type. This quantity is divided by the total cost of all classes average costs (MAQCST84) introduced between 1962 and 1983.

By keeping track of the number of ships in each class (denoted by NCLASS) and using the FREQ command in the SAS procedure Means, one can obtain:

1. The average value of each ratio for a major type weighted by each ship. (ex.: MRT/C is the avg. ratio of tonnage/dollar).
2. Also, the total cost of all ships introduced in the period 1962-1983 (SCST) can be obtained.
3. Slopes are again taken utilizing the GLM SAS procedure.However, each lead ship's ratio value has been multiplied by the number in that class that have been acquired during the period 1962-1983. Thus, ships with a large number in its class will be more influential in the regression line determination.

Then the weighted growth rates for weight 2 and weight 4 are created.

Weight two (WT2) is the sum over all major types of the growth rate times the number of ships introduced in that major type. This quantity is divided by the total number of ships introduced between 1962 and 1983.

Weight four (WT4) is the sum over all major types of the growth rate times the total cost of all ships in that major type. This is divided by the total acquisition cost of all ships introduced between 1962-1983.

The programs that were utilized to create these proportional growth rates by Method A are listed in Appendix A. They have been written so that the SAS steps in this chapter coincide with the appendix listing.

An additional consideration when utilizing the time-series regression technique is observing the resultant statistics. Weighting factors WT1 and WT3 only utilize the classes of ships in conducting the regression. Weighting factors WT2 and WT4 require each ship to be considered in the regression. Therefore, for each time period, there are

two sets of resultant statistics from the linear regression conducted on the major types of ships. These statistics provide a measure of the quality of the time-series regression model. Table XV provides the regression model statistics for the ratio of tonnage/dollar when weighing each class equally. Table XVI provides the statistics for the ratio of tonnage/dollar when weighing each ship equally during the period 1962 to 1983. Table XVII and Table XVIII provide these same statistics for crew member per dollar. Table XIX and Table XX provide these statistics for the

TABLE XV

Ratio Tons/Dollar Regression Statistics

Major Type	#Obs	Class Weight Coefficient	S.E.	R-Square
SSBN	4	-0.005	0.097	0.0016
SSN	7	0.136	0.17	0.1156
SS	2	-15.452	0.0	1
CGN	4	0.4775	0.99	0.921
AAW COMBT	6	-0.2163	0.12	0.436
ASW COMBT	7	-0.0122	0.48	0.00013
AMPHIB	9	2.055	1.79	0.158
MINESWEEP	0	0.0000	--	--
AUXILIARY	8	-0.2556	1.61	0.0042
TENDERS	5	0.5045	0.78	0.565
CV/CVS	2	0.4649	0.0	1
CVN	2	1.1572	0.0	1

ratio of generating capacity per dollar. And finally, Table XXI and Table XXII provide these statistics for units per dollar (millions) during the period 1962 to 1983.

TABLE XVI

Ratio Tons/Dollar Regression Statistics

Major Type	#Obs	Each Ship counts Coefficient	S.E.	R-Square
SSBN	35	-0.02171820	0.03	0.0154
SSN	78	0.35054470	0.025	0.72
SS	2	-15.45246881	0.0	1
CGN	8	0.50331573	0.057	0.93
AAW COMBT	45	-0.07524711	0.045	0.062
ASW COMBT	114	-0.30600536	0.11	0.07
AMPHIB	59	1.55522312	0.57	0.12
MINESWEEP	0	0.00000000	--	
AUXILIARY	36	-0.20148691	0.49	0.0049
TENDERS	15	0.78099518	0.34	0.29
CV/CVS	4	0.46495156	0.0	1
CVN	4	1.15723364	0.0	1

TABLE XVII

Ratio Crew/Dollar Regression Statistics

Major Type	#Obs	Class Weight Coefficient	S.E.	R-Square
SSBN	4	-0.0116	0.014	0.2582
SSN	7	-0.0039	0.007	0.0668
SS	1	0.0	--	--
CGN	4	0.0159	0.005	0.822
AAW COMBT	6	-0.0561	0.009	0.900
ASW COMBT	7	-0.112	0.041	0.599
AMPHIB	9	-0.0049	0.045	0.0017
MINESWEEP	0	0.0000	--	--
AUXILIARY	7	-0.0963	0.060	0.3399
TENDERS	5	0.125	0.191	0.124
CV/CVS	2	0.0277	0.0	1
CVN	2	0.0324	0.0	1

TABLE XVIII

Ratio Crew/Dollar Regression Statistics

Major Type	#Obs	Each Ship counts Coefficient	S.E.	R-Square
SSBN	35	-0.018	0.003	0.54
SSN	78	0.00037	0.001	0.0009
SS	1	0.0	--	--
CGN	8	0.017	0.003	0.86
AAW COMBT	45	-0.061	0.006	0.74
ASW COMBT	114	-0.16	0.008	0.785
AMPHIB	59	-0.0117	0.015	0.0099
MINESWEEP	0	0.0000	--	
AUXILIARY	35	-0.10	0.02	0.44
TENDERS	15	0.12	0.11	0.077
CV/CVS	4	0.028	0.0	1
CVN	4	0.03	0.0	1

TABLE XIX

Ratio KW/Dollar Regression Statistics

Major Type	#Obs	Class Weight Coefficient	S.E.	R-Square
SSBN	3	-0.1554	0.067	0.8435
SSN	7	0.1862	0.329	0.06
SS	1	0.0	--	--
CGN	4	0.7117	0.087	0.9707
AAW COMBT	6	-0.0042	0.079	0.0007
ASW COMBT	7	0.968	0.38	0.57
AMPHIB	9	-0.1265	0.831	0.0033
MINESWEEP	0	0.0000	--	--
AUXILIARY	6	0.6909	1.214	0.0749
TENDERS	5	3.74	1.197	0.165
CV/CVS	2	0.075	0.0	1
CVN	2	0.239	0.0	1

TABLE XX

Ratio KW /Dollar Regression Statistics

Major Type	#Obs	Each Ship counts Coefficient	S.E.	R-Square
SSBN	34	-0.13	0.021	0.54
SSN	78	0.585	0.042	0.72
SS	1	0.0	--	--
CGN	8	0.74	0.05	0.97
AAW COMBT	45	0.078	0.03	0.14
ASW COMBT	114	0.57	0.087	0.274
AMPHIB	59	-0.485	0.27	0.05
MINESWEEP	0	0.0000	--	
AUXILIARY	27	0.61	0.44	0.07
TENDERS	15	3.4	0.47	0.80
CV/CVS	4	0.075	0.0	1
CVN	4	0.24	0.0	1

TABLE XXI

Ratio Units/Dollar Regression Statistics

Major Type	#Obs	Class Weight Coefficient	S.E.	R-Square
SSBN	4	-6.39	0.000	0.8605
SSN	7	0.000032	0.000	0.0621
SS	2	-0.00994	0.000	1
CGN	4	0.000026	0.000	0.6969
AAW COMBT	6	-0.00011	0.000	0.72
ASW COMBT	7	-0.00028	0.00	0.444
AMPHIB	9	0.000037	0.000	0.0031
MINESWEEP	0	0.0000	--	--
AUXILIARY	8	0.000022	0.000	0.00055
TENDERS	5	-0.000064	0.000	0.0992
CV/CVS	2	0.000006	0.0	1
CVN	2	0.000012	0.0	1

TABLE XXII

Ratio Units /Dollar Regression Statistics

Major Type	#Obs	Each Ship counts Coefficient	S.E.	R-Square
SSBN	35	-0.000065	0.000	0.744
SSN	78	-0.00000024	0.000	0.000006
SS	1	0.0	--	--
CGN	8	0.000028	0.000	0.76
AAW COMBT	45	-0.00013	0.000	0.48
ASW COMBT	114	-0.000345	0.000	0.664
AMPHIB	59	0.00023	0.000	0.068
MINESWEEP	0	0.0000	--	--
AUXILIARY	36	-0.000014	0.000	0.000298
TENDERS	15	-0.000027	0.000	0.039
CV/CVS	4	0.0000006	0.0	1
CVN	4	0.000012	0.0	1

It is noted that generally, the models improved when each ship of the class is counted. However, the offsetting disadvantage to utilizing the individual ship weighting factor is that classes with more ships in the class are exerting a greater influence on the regression model. And thus, the classes with more ships are influencing the proportional growth rates for the major types of ships as well.

Several observations on Table XV through Table XXII are worthy of comment. The number of observations is approximately the same when class weight is utilized. When each ship counts equally,the number of observations becomes mixed. The Minesweep major type has no observations. The coefficients vary from table to table as expected. It is noted that the Units per Dollar ratio coefficients are very small in comparison with the other coefficients. Thus, the significant error of those values is small as well. The R-square statistic is quite erratic and shows comletely

different values for the different ratios of the same major type.

4. Alternatives

Two alternatives to the base case were conducted. The first alternative utilized a larger grouping of the major types. Since the base case showed that no new minesweepers were introduced during the period 1962-1983, that major type could be eliminated. The submarines were all classified as one major type (SSBN, SSN, and SS). The surface combatants were grouped as one major type. The auxiliaries and tenders were grouped together. And, the carriers were grouped together. The resultant grouping of five major types is listed in Table XXIII. The time-series regression technique was applied to these five major types of ships. The results are shown in Table XXIV. The results are very similar to the base case when thirteen major types of ships were categorized. The class count regression statistics are shown on Table XXV. The ship count regression statistics are shown on Table XXVI. The R-square statistics are not favorable and do show the non-homogeneity of Navy ships within the larger major types category.

TABLE XXIII

Alternative Grouping of Ships for Method A

Major Types	Type of Ships Included
Submarines	SSBN,SSN,AGSS,SS
Surface Combatants	AGMR,BB,CA,CC,CG,CGN,CLG DDG,DD,DE,DER,FF,FFG
Amphibious	APA,APB,APD,AVT,LCC,LFR LHA,LKA,LPA,LPD
Auxiliary	AE,AF,AFS,AG'S,AH,AK,AKL ANL,AO,AOE,AOG,AR's AD,AS
Aircraft Carriers	CV,CVS,CVN

TABLE XXIV

Method A Alternative Growth Rates Results

Time-Series Regression Technique
Revised Major Types
(During the Years 1962-1983)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1	-2.1075	0.0390169	1.73119	-0.3705
WT2	-1.2234	0.855873	2.87396	-0.057677
WT3	-2.3931	-0.10159	1.63035	-0.14454
WT4	-1.6007	0.841061	3.20534	-0.05297
AVG	-1.83	0.4086	2.36	-0.1564

TABLE XXV

Alternative Regression Statistics

Major Type	#Obs	Class count Coefficient	S.E.	R-Square
		RU/C		
SUBS	13	-0.00055	0.001	0.039
SURF COMBT	17	-0.00015	0.000	0.145
AMPHIB	9	0.00004	0.000	0.0031
AUXILIARY	13	0.00016	0.000	0.033
CV/CVN	4	0.000004	0.000	0.0274
		RT/C		
SUBS	13	-0.684	1.164	0.0304
SURF COMBT	17	-0.092	0.192	0.0152
AMPHIB	9	2.055	1.794	0.158
AUXILIARY	13	0.64	1.06	0.032
CV/CVN	4	0.78	0.61	0.449
		RP/C		
SUBS	12	-0.0084	0.0064	0.145
SURF COMBT	17	-0.063	0.024	0.31
AMPHIB	9	-0.049	0.045	0.0017
AUXILIARY	12	-0.1454	0.073	0.287
CV/CVN	4	0.0141	0.048	0.042
		RKW/C		
SUBS	11	-0.037	0.227	0.003
SURF COMBT	17	0.335	0.192	0.168
AMPHIB	9	-0.127	0.83	0.0033
AUXILIARY	11	1.08	0.774	0.178
CV/CVN	4	0.203	0.051	0.89

The second alternate to the base case increased the period of observation from 1939 to 1983. The same thirteen categories of major types listed in the base Method A case were utilized. The results of the time-series regression technique on this alternative case is shown on Table XXVII . The R-square statistic for the second alternative are similiar to the base case, but they are unique. The second alternative regression statistics are not displayed.

TABLE XXVI

Alternative Regression Statistics

Major Type	#Obs	Each Ship counts Coefficient	S.E.	R-Square
		RU/C		
SUBS	115	-0.00008	0.000	0.0047
SURF COMBT	167	-0.00014	0.000	0.1024
AMPHIB	59	0.00023	0.000	0.068
AUXILIARY	51	0.00007	0.000	0.0078
CV/CVN	8	0.000005	0.000	0.065
		RT/C		
SUBS	115	0.092	0.164	0.003
SURF COMBT	167	0.043	0.08	0.002
AMPHIB	59	1.56	0.57	0.117
AUXILIARY	51	0.31	0.47	0.0091
CV/CVN	8	0.47	0.26	0.346
		RP/C		
SUBS	114	-0.0082	0.002	0.136
SURF COMBT	167	-0.075	0.009	0.296
AMPHIB	59	-0.0117	0.015	0.00998
AUXILIARY	50	-0.126	0.034	0.22
CV/CVN	8	-0.0098	0.020	0.040
		RKW/C		
SUBS	11	0.4556	0.059	0.349
SURF COMBT	17	0.574	0.058	0.37
AMPHIB	9	-0.485	0.273	0.053
AUXILIARY	11	0.9035	0.353	0.141
CV/CVN	4	0.2048	0.023	0.9325

C. METHOD B (FORWARD DIFFERENCING AGGREGATION TECHNIQUE)

1. Theory Description

An alternative to the simple regression of Method A is to utilize a moving average model. It is recalled that the Navy Resource Dynamics Model is making predictions about naval force levels far into the future. The length of projection and uncertainty about the future demand a simplistic approach. The simplest of the moving average models is based on assuming that a likely value for the

TABLE XXVII

Method A Alternative Growth Rates Results

Time-Series Regression Technique
Revised Years
(During the Years 1939-1983)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1	-3.4906	-2.6144	0.254883	-0.49694
WT2	-4.5232	-2.72	3.16183	-0.070232
WT3	-1.913	-0.69124	0.367762	-0.2237
WT4	-2.8441	-1.1406	1.52872	-0.039746
AVG	-3.19	-1.79	1.329	-0.207

series' next value is a simple average of its values over several recent time periods. This simple, straightforward method will be called the forward differencing method, Method B.

The forward differencing method assumes that a good forecast will be given by the simple average of its past values. This is a strong assumption. However, the Navy is composed of a non-homogeneous collection of ships, which are required to fulfill many different missions and diverse commitments. This non-homogeneity working in concert with the changes in the Navy's mix overtime, implies that the simplest of models may be the most accurate.

Forward differencing or backward differencing could have been utilized in determining the moving average values. Forward differencing was selected arbitrarily to coincide with the notion that it is the future Navy that this analysis is attempting to predict. The forward differencing technique works by comparing two values that are in timed

order. For example, the value at time t is compared with the value at time t+1. By subtracting the two values, a difference is formed. This is repeated at time t+1 when its value is compared with time t+2,etc. This continues for the full time period dicussed (ie. five years for the base case) Backward differencing would be comparing the values at time t,t-1, t-2,etc.

An example of forward differencing is the ratio of Units per Million dollars of the Spruance class. On Table III, the average cost of the Spruance class ship in 1981 was 272.658 million and in 1982 was 272.658 million dollars. By taking the reciprocal of both these values to form the ratio (Units/ cost) and then subtracting the two values the difference value for 1981 is obtained. When this value (-0.0000020592) is divided by the reciprocal of 272.505, the growth rate (GRU/C) for the Spruance class in 1981 is obtained (-0.00056) as is shown on Table IV . Cost per unit is obtained by taking the difference between the two average costs (272.658 - 272.505) and then dividing by the average cost per unit in 1981 (272.505) . The resultant growth rate of Cost (value) per Unit is 0.00056. As previously noted, this is equal in value and opposite in sign to the growth rate GRU/C.

One of the disadvantages of the moving average model is that it does not provide any readily interpretable information about forecast confidence. Since regression is not used to estimate the moving average model, test and confidence bound statistics are not as accessible as those from regression models. It is the stochastic or "unexplained" component in the time-series that creates the errors in forecasting. It must be pointed out again that the utilization of this analysis is for describing long range growth effects on the U.S. Navy's ships.

Another recognized problem of the moving average model is time dependency. Time dependency arises when the variable at time t bears a close relationship to the variables measured at times t + 1, t + 2, etc. As previously mentioned, the fleet cannot change its composition in a short period of time. There does exist time dependency in this forward differencing technique. However, it does not prevent the analysis from being continued and argued in its favor.

2. <u>SAS Steps</u>

The actual procedural steps using SAS to obtain the acquisition cost growth rates for the entire Navy by Method B follow:

1. Starting with the entire data base, USNS and ships with less than 300 tons are deleted.

2. The remaining data base is then sorted by classes (or types) of ships.

3. Then, the commissioned active or reserve ships for each year (1978 to 1983 in the base case) are created. By deleting the ships who have retired and adding those ships who were launched two years ago, it is an approximate list of active/reserve ships in commission that particular year.

4. In each of the years, the number of observations, average value and summation for each of the following categories are saved for each class (type) of ship: number in the class, tonnage, crewsize, generating capacity and acquisition cost in constant (1984) dollar.

5. For each class (type) of ship in each year the ratios are created. For example the ratio of tonnage to acquisition cost = RT/C = average tonnage (MTON)/average cost of all commissioned units in that year. The other ratios are RU/C, RKW/C, RP/C.

6. Using the SAS difference function described in [Ref. 6, p.440], the forward differences are determined automatically by SAS.

7. Then, the proportional growth rates for each class (or type) and each year are formed by dividing the forward difference values by the ratios (in Step 5 above) to obtain the growth rates, namely: GRU/C, GRT/C, GRKW/C, and GRP/C.

3. Weighting Factors

Once the four growth rates have been formed, the four weighting processes begin.

Weight One (WT1) is determined by using the SAS procedure means to find the average value of the four growth rates for each class (or type) over all the years studied. Then using the SAS Procedure Means again, the average growth rate over all classes (or types) of ships combined together is the aggregated growth rate for all ships weighting each class equally.

Weight two (WT2) is determined by multiplying the growth rate of each class (type) by the number of ships (denoted by TOTOBS) commissioned in that year and in that class (type). SAS Procedure Means is utilized to obtain the sum of all these growth rates multiplied by numbers of ships. An example is the sum for a particular year of the

growth rate of crewsize/cost times the number in that class denoted by SYRNFC. This quantity is divided by the sum total of all ships commissioned in all the years studied (NOSHIP). This will provide the weighted growth rates so that each ship counts equally.

Weight three (WT3) is determined by multiplying the growth rate for each class (type) and year by the average acquisition cost of a ship in that class (type) that particular year. The sum of these values for each class (type) is obtained using the SAS Procedure Means. Each of these sums is divided by the sum of average acquisition costs for that class (type) of ship. And finally, all of these values are averaged to obtain the aggregated growth rates weighting equally by the class (type) value.

Weight four (WT4) is determined by multiplying each growth rate in each year by the total cost of all ships in commission in that year. These quantities are all summed for each growth rate. Then, this quantity is divided by the total sum of all commissioned ships' acquisition cost for all years studied. The result is the growth rates for the entire Navy with each ship's value being weighted equally.

A typical program that was utilized to create these proportional growth rates by Method B is listed in Appendix B. IT has been written so that the SAS steps in this chapter coincide with the appendix listing.

4. Alternatives

Two alternatives to the base case of 1978 to 1982 were made. The first alternative utilizing the same SAS steps and weighting factors was produced using a ten year time period 1973 to 1982. The results of this alternative are presented in Table XXVIII .

TABLE XXVIII

Method B Alternate Growth Rates Results

Forward Differencing Technique
of Class (C) and Type (T)
(During the Years 1973-1982)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1C	-3.5108	-0.3481	-0.3531	-3.3918
WT1T	-3.2134	-1.1197	0.159313	-1.1475
WT2C	-0.24702	0.136231	0.23837	-0.17149
WT2T	-1.5978	-0.21015	0.722138	-1.3645
WT3C	-4.1837	-0.72884	-0.17343	-4.2319
WT3T	-3.7023	-1.5104	0.238862	-1.2572
WT4C	-0.75938	0.219086	0.259182	-0.55207
WT4T	-1.3092	0.152064	0.73928	-0.9303
Avg	-2.315	-0.564	0.175	-1.667

The second alternative also used the same SAS procedures and weighting factors as the base case. However, it was based on the time period of 1963 to 1982. The second alternative results are displayed in Table XXIX .

The base case was chosen over the other two alternatives for two reasons. The first reason was that the results more closely resemble Method A's base case results. The second reason was the tremendous influence in the late 60's and early 70's of Navy force size. Over the course of 6 years, the U.S. Navy was reduced by one half of the number of ships in the Navy. The Navy changed from over 1,000 active units to less than 600 units in a short period of time. As was shown in the case of the Spruance class destroyers and their introduction into the destroyer force, the decommissionings of World War II built ships were having a dramatic effect on the Navy's composition. Elimination of

TABLE XXIX

Method B Alternate Growth Rates Results

Forward Differencing Technique
of Class (C) and Type (T)
(During the Years 1962-1982)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1C	-4.8427	-1.6578	-1.7047	-3.4664
WT1T	-4.4569	-1.9062	-1.598	-2.0775
WT2C	-1.2091	-0.4252	0.0127654	-0.29934
WT2T	-1.7068	-0.77934	-0.10305	-1.2047
WT3C	-5.5267	-1.974	-1.4616	-4.1191
WT3T	-4.8724	-2.2357	-1.488	-2.2983
WT4C	-2.7217	-0.90091	-0.16563	-0.83403
WT4T	-1.4212	-0.44723	0.247211	-0.84685
Avg	-3.344	-1.292	-0.782	-1.905

that unique charge in the fleet removes much of the time dependency and change in force composition due to decommissionings. Thus, the shorter lag period of five years is the preferred case.

D. METHOD C (FORWARD DIFFERENCING ON THE LEAD SHIPS OF EACH CLASS)

1. Discussion

As an alternative to Method A and Method B, an attempt was made to combine the two techniques. Method C was generated by creating the lead ship of each class as in the time-series regression technique of Method A. This includes replacing the lead ship cost with the average cost

(MAQCST84) of the ships in the class. From this revised data base, the same technique as in Method B was utilized to create and appropriately weight the results.

As mentioned in the results section of this chapter, Method C is not recommended. Additionally, it does not use the same weighting factors as the other two methods. Method C is only presented as a failed technique - one that did not work. There were no alternative cases to Method C.

IV. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

A. GENERAL COMMENTS

As described in Chapter I, it was the intent of this analysis to observe past historical growth rates of the acquisition cost of U. S. Navy ships and their interaction with the changes in crew size, tonnage and electrical generating capacity. These growth rates are indicators of part of the flow of allocating Navy resources over time. They were studied to provide as accurately as possible a forecast of the future Navy's growth trends. Specifically, this analysis supports the ongoing Navy Resource Dynamics Model and provides an updated view of the acquisition cost of U.S. Navy ships.

The preferred results of Method A and Method B are shown in Chapter III on Tables IX and X. They have been combined and are displayed in Table XXX . Method C was found unacceptable and is therefor not displayed. The four proportional acquisition cost growth rates studied are unit per dollar(GRU/C), tonnage per dollar(GRT/C), generating capacity per dollar(GRKW/C) and crewmember per dollar(GRP/C). The two acceptable methods of aggregating the cost growth rates are as follows:

1. Method A utilizes a linear least-squares time-series regression technique on major types of ships and then aggregates the data into the total fleet.
2. Method B conducts a moving aggregation of cost growth rates by keeping track of all the commissioned ships in a particular year, compares yearly totals by class and type of ship utilizing a forward differencing function and then aggregates the results.

TABLE XXX

Combined Final Results

Method A Cost Growth Rates Results
Time-Series Regression Technique
(During the Years 1962-1983)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1	-2.1899	0.211547	3.17215	-0.14756
WT2	-2.1121	0.613916	2.20314	-0.03784
WT3	-0.80782	1.37164	2.33942	0.338946
WT4	-1.5056	1.1344	2.0827	0.061241
AVG	-1.654	0.833	2.449	0.0537

Method B Cost Growth Rates Results
Forward Differencing Technique
of Class(C) and Type(T)
(During the Years 1978-1982)
(Expressed in Percentages)

	GRU/C	GRT/C	GRKW/C	GRP/C
WT1C	-3.0414	-0.8234	-0.61234	-3.9542
WT1T	-1.0285	-1.2711	0.717061	-1.9624
WT2C	-0.30492	-0.0086021	0.199299	-0.48512
WT2T	-1.3888	0.15829	1.30677	-1.5183
WT3C	-3.5695	-1.261	-0.47483	-4.7931
WT3T	-1.0678	-1.3383	0.753308	-2.0511
WT4C	-0.93171	-0.033344	0.0713668	-1.1987
WT4T	-1.1813	0.257659	1.11948	-1.3014
Avg	-1.564	-0.540	0.385	-2.158

Both historical growth rate computations are analyzed using four different weights, namely:

1. WT1-Each class of ship weighted equally;
2. WT2-Each ship weighted equally;
3. WT3-Each class weighted by the average acquisition value of that class; and

4. WT4-Each ship being weighted by its own acquisition cost. The choice of which weighting factor to use is not clear. Therefore, an average, denoted by AVG, of all four weighting factors is presented in the tabulated results.

The incorporation of years 1962 to 1983 for Method A, the time-series regression technique, were chosen to reflect the majority of classes of ships which are presently existing in the active U.S. Navy as it exists today. Additionally these years are coincident with the same beginning year as Dr. Clark's previous work in [Ref. 2]. Method A thus does not include ships commissioned before 1962 in its computations. Thirteen major categories of ship types were selected as the preferred grouping for regression analysis. They were displayed in Table X . These major types of ships were chosen to reflect as homogeneous a grouping of ship types as possible.

The results of Method B using the forward differencing technique utilizes a five year time period, namely 1978 to 1982. The ships are aggregated by class or by type in each year before being aggregated into the whole Navy. For this reason, both class and type results are displayed in Table XXX for each weighting factor and are both utilized when all the weighting factors are averaged.

Over a significant period of time and with a homogeneous type of ship the results of Method A and Method B tend to converge and approach one another in value. How to best capture the convergence and try to represent a heterogeneous body of ships in the aggregate was the art of this study. As described in Chapter I, there existed an influence on the Navy's basic parameter characteristics as the World War II ships were being decommissioned in the late 1960's and early 1970's. Since the years chosen for Method A was 1962 to 1983 and Method A only studied new platforms entering the

Fleet, it was essentially describing the newer active ships. By only utilizing the last five years, Method B eliminated the decommissionings conducted in the late 60's/early 70's and in that way captures the essence of recent growth.

B. COMPARISON OF METHODS AND WEIGHTING FACTORS

It is essential to review the advantages and disadvantages of each method in order to compare the methodology utilized to produce the aggregate growth rates for the entire fleet. Since Method C has been dismissed as inappropriate, it will not be discussed. The remaining two methods, time-series regression technique and the forward differencing technique, have both been affected by several factors. These include the effects of aggregation of a hetereogeneous group of ships, data limitations, inflation effects and the learning curve effect as dicussed below. Both Method A and Method B are affected by the choice of which weighting factor to use and their respective responses differ. The case of aggregation difficulties was presented in Chapter I on the discussion of the Spruance class ships and their effect on the destroyer (DD) type of ship. These clear inter-relationships to acquisition cost are not always obvious when the aggregation is accomplished at the major type and fleet level. The data base limitations principally affected the forward differencing technique, however, there were several instances when inconsistency existed between the number of observations of the same major types in the SAS regression GLM procedure. As discussed in Chapter II, alternative deflator scales could have been utilized which would have produced different results in both methods. And finally, an example of the learning curve effect on the Spruance class was shown visually in Figure 1.3. Instead of

using the average acquisition cost in both methods, it was possible to have utilized the first follow-on ship (the second ship of the class), or another consistent follow-on ship. All of the above comments have a direct input to the resultant growth rates that are produced. The magnitude and sensitivity of their impact requires additional research.

The time-series regression technique, Method A, has many advantages. It is a simple, statistical modelling approach. The effects on trends are felt immediately since, under certain conditions, the linear regression produces the maximum likelihood estimates. It utilizes only a few observations. In the preferred time period, 1962 to 1983, and the preferred grouping of ships as shown in Table X, the time-series regression technique only required a total of 57 observations. It is capable of producing variance estimates in its results, as shown in the regression statistic tables.

The time-series regression technique, Method A, has advantages as dicussed above. It does have some disadvantages in its usage. First of all, the time-series regression technique requires homogeneous groupings. As previously mentioned, the U.S. Navy is composed of diverse and unique platforms that are oriented towards different missions and different utilizations. Secondly, by using the lead ship in each class as the reference point for the whole class, there is a subtle underlying implication that, in effect, all ships in the class are built in the same year. This applies to weighting factors WT2 and WT4 when each ship of the class has equal weighting. Another concern with using the regression technique is the poor quality of the R-square statistics. This poor showing in the R-square statistic shows the variability of the preferred groupings of major types. More alternative groupings, especially in the amphibious and auxiliary major types, need to be attempted to try to improve the overall R-square statistics

values. Additionally, as explained in [Ref. 10, p.352], it is important to always check for autocorrelation when using the time-series regression technique by testing with the Durbin Watson statistic.

The forward differencing technique has advantages and disadvantages of its own. First of all, Method B is simple in its design as a moving average model. It is easy to group ships using the Stastical Analysis System and to see the individual classes and types over time using the SAS "by" command. Thus, it is easy to observe unique platforms and classes showing changes in the trends at the lower levels of aggregation. This technique does not require grouping into major types before applying weighting factors as is required in the time-series regression.

Many of the disadvantages of the forward differencing technique in Method B have previously been mentioned. The results are affected by time dependency in its calculations. In the calculations of this data base, the forward differencing method combines the active and reserve ships in its calculations. The forward differencing technique provides no forecast confidence, only point estimates of the growth trends. Therefore, there are no confidence limits readily available. As previously shown in Chapter I for the destroyer type ship, it is influenced by the effect of decommissioning. It would be advantageous to have a complete data base with the exact commissioning dates and periods of active service. As mentioned in Chapter II, the reactivation of inactive ships, specifically the class of battleships, was not reflected in this technique.

It is also appropriate to comment on the weighting factor results. In most cases, weighting factors tended to operate in pairs. Weights WT1 and WT3 which gave each class equal weight in numbers and average acquisition cost, respectively, produced growth rates that closely resembled

one another. Weights WT2 and WT4, which gave each ship and each ship acquisition value respectively equal weight, produced growth rates that tended to be close together. This tendency of the weighting factors was more pronounced in the moving average technique. It also had more influence on the regression technique when the period studied was increased to 1939 to 1983. In the preferred results of the time-series regression technique in Table IX, the results were different. With the exception of the growth rate in generating capacity per dollar (GRKW/C), the weighting factor pairs are WT1 and WT2 against WT3 and WT4. This alignment is generated by the fact that weighting factors WT1 and WT2 weigh by number of observations and weighting factors WT3 and WT4 involve acquisition cost weights.

The average of the four weighting factors listed in the result tables has no statistical basis. As was previously mentioned, it was accomplished since there is no clear choice of which weighting factor to utilize. They all four have merit and could be utilized alone.

In the forward differencing technique of Method B, there is the additional comparison of initial grouping by classes or types. This shows that it is possible to aggregate at the type of ship level using the moving average technique. This is important when one is forecasting the future Navy and the policy makers are interested in a particular type of ship. This <u>can be</u> utilized to forecast the future cost growth of that platform type.

An additional advantage occurs when both methods are utilized. It is the simple reason that they can be compared. Positive reinforcement occurs when you obtain similar results using two entirely different methods to obtain those results. This is especially true in this analysis since the two methods tend to converge under appropriate conditions. If the results are different, then

it automatically implies further investigation of the results for causative factors that could possibly provide the different results.

C. CONCLUSIONS

The results of this thesis are succinctly shown in Table XXX. Although growth rates are simplistic in concept, aggregation of the non-homogeneous ships that compose the U.S. Navy imposed complications to the analysis. The results are based upon the numerous assumptions listed throughout this study.

The two preferred methods in Table XXX show mixed results. It is obvious that the growth rate in acquisition cost per unit (reciprocal of GRU/C) is about one and one half to two percent per year. This is consistent between the two methods. In the second column all weightings show a decrease in the value of the annual cost per ton growth rate from the time-series regression technique. Conversely, the forward differencing tecnnique indicates an increase in cost per ton per year, with the exception of WT2T and WT4T when the ships are grouped by type in each year before aggregating. This is not as reinforcing as the first column results.

The growth rate in acquisition cost per generating capacity shows a decrease in all categories except WT1C and WT3C of the forward differencing technique. The resultant values of the time-series regression technique are all consistently greater in magnitude than the Method B results. Of the four growth rates studied, this one has the least validation in the data base and consequently is viewed with the greatest skepticism.

The growth rate in crewmember per acquisition cost (GRP/C) shows the largest differential between the two methods. All the methods and different time periods indicate a negative growth rate in crew member per acquisition cost except WT3 and WT4 for the time-series regression technique. These two weights were large enough in magnitude to cause the average of the four weighting factors to show a slightly negative growth in acquisition cost per crew member in the time-series regression technique. Because of the uniqueness of this result, the growth rate of acquisition cost per crew member should be studied further.

D. RECOMMENDATIONS FOR FUTURE RESEARCH

This macro-analysis is only a portion of defining the evolutionary process of changes in the fleet. It provides only a small insight into the future direction of the fleet as it continues to modernize. There exist many other elements of the Navy modernization process which can be parameterized and further validated in support of the Resource Dynamics Model. These are growth rates external to this thesis.

There do exist several improvements and areas of further research in studying the long term relationships between acquisition cost, fleet tonnage, fleet manning and fleet electrical generating capacity of U.S. Navy ships. First of all, this study only looked at the empirical growth rates per acquisition dollar. Several other historical growth rates could have been studied concurrently using the same data base and computer programs. These include the following: tons per unit, crew members per ton, crew members per unit, crew members per generating capacity, generating capacity per ton, and generating capacity per

unit. It is necessary to study all these proportional growth rates in order to transform the historical empirical data into a predictive model such as Resource Dynamics.

An additional area of improvement would be to consider different major types of ships when conducting the time-series regression technique. By further analysis, it should be possible to improve the R-square statistics.

Another addition to this analysis would be considering the Military Sealift Command ships. USNS units are providing an increasingly active role in fleet operations and there may be different growth rate trends when they are included with the U.S. Navy fleet.

An additional extension to this analysis would be to consider modification costs in observing the total asset value of the the force. The flow of resources towards the trade-off of major repair of older units versus new acquisition involves major decision makers who shape the Navy's budget.

APPENDIX A

METHOD A COMPUTER PROGRAMS

```
*************************************************************
                        PROGRAM I
******* This Program Creates the Slopes for *********
*******   Method A Base Case (class count)   *********
*******    The SAS Steps are explained in    *********
*******              Chapter IIIB            *********
*************************************************************
//RD  JOB (1231,0196),'DOUG SMARTT',CLASS=C
//*MAIN ORG=NPGVM1.1231P
//  EXEC SAS
//FROM   DD DISP=(OLD,KEEP),DSN=MSS.S1231.GWUSAS2
//SYSIN   DD *
DATA  XX;
   SET FROM.DOUG;
**************** Step 1   *********************
        IF CLASS = : 'T' THEN DELETE;
        IF CLASS = : 'P' THEN DELETE;
**************** Step 2   *********************
   COMMYR = LNCHYR + 2;
**************** Step 3   *********************
   IF COMMYR < 62 THEN DELETE;
   IF COMMYR > 83 THEN DELETE;
   PROC SORT; BY TYPE;
**************** Step 4   *********************
   PROC MEANS NOPRINT;BY TYPE;
        VAR AQCST84 ;
        OUTPUT OUT = AVG
        N = NCLASS
        MEAN= MAQCST84;
**************** Step 5   *********************
DATA  CV;
   MERGE XX AVG;BY TYPE;
             IF FIRST.TYPE THEN GO TO MISS;
                  ELSE DELETE;
             MISS: ;
   PROC SORT;BY DCODE COMMYR TYPE;
   DATA ALL5;
     SET CV;
       IF CLASS ='DD' OR CLASS = 'DE' OR CLASS = 'DER'
     OR CLASS = 'FF' OR CLASS = 'FFG' THEN DCODE = 13;
**************** Step 6   *********************
             RTC = TONNAGE/MAQCST84;
             RPC = CREW/MAQCST84;
             RKWC = GENCAP/MAQCST84;
             RUC = 1/MAQCST84;
**************** Step 7A *********************
   PROC SORT;BY DCODE COMMYR TYPE;
   PROC MEANS ; BY DCODE;
        VAR RTC RPC RKWC RUC MAQCST84 ;
   DATA XX2;
        SET ALL5;
**************** Step 7B *********************
   PROC GLM; BY DCODE;
        MODEL RTC = COMMYR;
   PROC GLM; BY DCODE;
        MODEL RPC = COMMYR;
   PROC GLM; BY DCODE;
        MODEL RKWC = COMMYR;
   PROC GLM; BY DCODE;
```

```
     MODEL RUC = COMMYR;
*** This Program produces the slope values      ***
*** (class count) that will be used in the      ***
*** next program (Program II) to compute the    ***
*** growth rates with weights WT1 and WT3       ***
/*
//
```

```
***************************************************************
                         PROGRAM II
*******    This Program Provides Method A    *********
******* Base Case(class count) Growth Rates.*********
******* The SAS Steps and Weighting Factors *********
*******  are explained in Chapter IIIB      *********
***************************************************************

//RD   JOB (1231,0196),'DOUG SMARTT',CLASS=C
//*MAIN ORG=NPGVM1.1231P
//   EXEC SAS
//FROM    DD DISP=(OLD,KEEP),DSN=MSS.S1231.GWUSAS2
//SYSIN    DD *
DATA  SL1;
*** These are the Slopes generated from Program I ***
INPUT DCODE  DRTC ;
   CARDS;
1               -0.00553155
2                0.13598652
3              -15.45246881
4                0.47753474
5               -0.21629168
6                2.05478981
7                 0.00000000
8                 0.25589127
10                0.50453051
11                0.46495156
12                1.15723364
13               -0.01215328
DATA  SL2;
INPUT DCODE  DRPC ;
   CARDS;
1                -0.01160704
2                -0.00390657
3                 0.00000000
4                 0.01591768
5                -0.05614286
6                -0.00493634
7                 0.00000000
8                -0.09624676
10                0.12468173
11                0.02773055
12                0.03240144
13               -0.11199387
DATA  SL3;
INPUT DCODE  DRKWC ;
   CARDS;
1                -0.15536545
2                 0.18618340
3                 0.00000000
4                 0.71165228
5                -0.00414065
6                -0.12655485
7        0.00000000
8                 0.69096446
10                3.73792790
11                0.07500841
12                0.23940464
13                0.96785357
DATA  SL4;
INPUT DCODE  DRUC ;
   CARDS;
1                -6.3905281E-05
2                -3.2006691E-05
3                -0.00993778
4                2.5579064E-05
5                -0.00011038
6                3.7455635E-05
7                 0.00000000
```

```
8               2.1617566E-05
10             -6.4086069E-05
11              6.2507006E-06
12              1.1970232E-05
13             -0.00027976
DATA  SLOPES;
   MERGE SL1 SL2 SL3 SL4;BY DCODE;
DATA  XX;
   SET FROM.DOUG;
        IF CLASS = : 'T' THEN DELETE;
        IF CLASS = : 'P' THEN DELETE;
   COMMYR = LNCHYR + 2;
   IF  COMMYR < 62 THEN DELETE;
   IF  COMMYR > 83 THEN DELETE;
   PROC SORT; BY TYPE;
   PROC MEANS NOPRINT;BY TYPE;
        VAR AQCST84 ;
        OUTPUT OUT = AVG
        N = NCLASS
        MEAN= MAQCST84
        SUM = SAQCST84;
DATA  CV;
   MERGE XX AVG;BY TYPE;
             IF FIRST.TYPE THEN GO TO MISS;
                  ELSE DELETE;
             MISS: ;
   PROC SORT;BY DCODE COMMYR TYPE;
   DATA ALL5;
     SET CV;
      IF CLASS = 'DD' OR CLASS = 'DE' OR CLASS ='DER'
   OR CLASS = 'FF' OR CLASS = 'FFG' THEN DCODE = 13;
             RTC = TONNAGE/MAQCST84;
             RPC = CREW/MAQCST84;
             RKWC = GENCAP/MAQCST84;
             RUC = 1/MAQCST84;
   PROC SORT;BY DCODE COMMYR TYPE;
   PROC MEANS ;BY DCODE;
        VAR RTC RPC RKWC RUC MAQCST84 ;
             OUTPUT OUT = SUMS
                  N = S1 S2 S3 S4 NCST
               MEAN = MRTC MRPC MRKWC MRUC S5
                SUM = S6 S7 S8 S9 SCST;
   DATA XX2;
        MERGE SUMS SLOPES; BY DCODE;
   PROC PRINT;
        VAR DCODE NCST SCST MRTC MRPC
      MRKWC MRUC DRTC DRPC DRUC DRKWC; DATA XX3;
        SET XX2;
****************** Step 8  **********************
   GRTC = DRTC/MRTC;
   GRUC = DRUC/MRUC;
   GRKWC = DRKWC/MRKWC;
   GRPC = DRPC/NCST;
   W1TC = GRTC*NCST;
   W1UC = GRUC*NCST;
   W1KWC = GRKWC*NCST;
   W1PC = GRPC*NCST;
   W3TC = GRTC*SCST;
   W3UC = GRUC*SCST;
   W3KWC = GRKWC*SCST;
   W3PC = GRPC*SCST;
   PROC MEANS ;
        VAR W1TC W1PC W1KWC W1UC
            W3TC W3PC W3KWC W3UC;
        OUTPUT OUT = BSUM
        SUM =SW1TC SW1PC SW1KWC SW1UC
            SW3TC SW3PC SW3KWC SW3UC;
DATA XX4;
        SET SUMS ;
```

```
   PROC MEANS ;
        VAR NCST SCST;
        OUTPUT OUT = HIT
             SUM = SNSHPS SSCST;
DATA XX5;
      MERGE BSUM HIT;
   W1GRTC = SW1TC/SNSHPS;
   W1GRUC = SW1UC/SNSHPS;
   W1GRKWC = SW1KWC/SNSHPS;
   W1GRPC = SW1PC/SNSHPS;
   W3GRTC = SW3TC/SSCST;
   W3GRUC = SW3UC/SSCST;
   W3GRKWC = SW3KWC/SSCST;
   W3GRPC = SW3PC/SSCST;
   PROC PRINT ;
        VAR SW1TC SNSHPS SSCST;
   PROC PRINT ;
        VAR W1GRTC W1GRPC W1GRKWC W1GRUC
            W3GRTC W3GRPC W3GRKWC W3GRUC;
/*
//
```

```
*************************************************************
                       PROGRAM III
******* This Program Creates the Slopes for *********
*******    Method A Base Case (ship count)    *********
*******      The SAS Steps are explained in    *********
*******               Chapter IIIB             *********
*************************************************************
//RD  JOB (1231,0196),'DOUG SMARTT',CLASS=C
//*MAIN ORG=NPGVM1.1231P
//  EXEC SAS
//FROM    DD DISP=(OLD,KEEP),DSN=MSS.S1231.GWUSAS2
//SYSIN   DD *
DATA  XX;
    SET FROM.DOUG;
****************** Step 1   **********************
         IF CLASS = : 'T'  THEN DELETE;
         IF CLASS = : 'P'  THEN DELETE;
****************** Step 2   **********************
    COMMYR = LNCHYR + 2;
****************** Step 3   **********************
    IF COMMYR < 62 THEN DELETE;
    IF COMMYR > 83 THEN DELETE;
    PROC SORT;  BY TYPE;
****************** Step 4   **********************
    PROC MEANS NOPRINT;BY TYPE;
         VAR AQCST84 ;
         OUTPUT OUT = AVG
         N = NCLASS
         MEAN= MAQCST84;
****************** Step 5   **********************
DATA  CV;
    MERGE XX AVG;BY TYPE;
              IF FIRST.TYPE THEN GO TO MISS;
                   ELSE DELETE;
              MISS: ;
    PROC SORT;BY DCODE COMMYR TYPE;
    DATA ALL5;
     SET CV;
      IF CLASS ='DD' OR CLASS = 'DE' OR CLASS = 'DER
   OR CLASS = 'FF' OR CLASS = 'FFG' THEN DCODE = 13;
****************** Step 6   **********************
              RTC = TONNAGE/MAQCST84;
              RPC = CREW/MAQCST84;
              RKWC = GENCAP/MAQCST84;
              RUC = 1/MAQCST84;
****************** Step 7A  **********************
    PROC SORT;BY DCODE COMMYR TYPE;
    PROC MEANS ;BY DCODE;
         VAR RTC RPC RKWC RUC MAQCST84 ;
    DATA XX2;
         SET ALL5;
****************** Step 7B **********************
    PROC GLM;BY DCODE;
         MODEL RTC = COMMYR;
    PROC GLM;BY DCODE;
         MODEL RPC = COMMYR;
    PROC GLM;BY DCODE;
         MODEL RKWC = COMMYR;
    PROC GLM;BY DCODE;
         MODEL RUC = COMMYR;
*** This Program produces the slope values      ***
*** (ship count) that will be used in the       ***
*** next program (Program IV) to compute the    ***
*** growth rates with weights WT2 and WT4       ***
/*
//
```

```
*******************************************************************
                          PROGRAM IV
*******    This Program Provides Method A      *********
******* Base Case(ship count) Growth Rates.  *********
******* The SAS Steps and Weighting Factors  *********
*******  are explained in Chapter IIIB        *********
*******************************************************************

//RD   JOB  (1231,0196),'DOUG SMARTT',CLASS=C
//*MAIN ORG=NPGVM1.1231P
//   EXEC SAS
//FROM    DD DISP=(OLD,KEEP),DSN=MSS.S1231.GWUSAS2
//SYSIN    DD *
DATA  SL1;
** These are the Slopes generated from Program III **
INPUT DCODE  DRTC ;
   CARDS;
1                -0.02171820
2                 0.35054470
3               -15.45246881
4                 0.50331573
5                -0.07524711
6                 1.55522312
7                 0.00000000
8                -0.20148691
10                0.78099518
11                0.46495156
12                1.15723364
13               -0.30600536
DATA  SL2;
INPUT DCODE  DREC ;
   CARDS;
1                -0.01774463
2                 0.00037425
3                 0.00000000
4                 0.01683012
5                -0.06069935
6                -0.01170313
7                 0.00000000
8                -0.10233676
10                0.11961610
11                0.02773055
12                0.03240144
13               -0.15658626
DATA  SL3;
INPUT DCODE  DRKWC ;
   CARDS;
1                -0.12970188
2                 0.58497305
3                 0.00000000
4                 0.73618327
5                 0.07844150
6                -0.48523422
7                 0.00000000
8                 0.60569160
10                3.36098225
11                0.07500841
12                0.23940464
13                0.56751293
DATA  SL4;
INPUT DCODE  DRUC ;
   CARDS;
1                 -6.4532837E-05
2               -2.4035199E-07
3               -0.00993778
4                2.8105498E-05
5               -0.00013059
6                0.00022835
7                0.00000000
```

```
8              -1.3499559E-05
10             -2.6607963E-05
11              6.2507006E-06
12              1.1970232E-05
13             -0.00039499
DATA  SLOPES;
   MERGE SL1 SL2 SL3 SL4;BY DCODE;
DATA  XX;
   SET FROM.DOUG;
        IF CLASS = : 'T' THEN DELETE;
        IF CLASS = : 'P' THEN DELETE;
   COMMYR = LNCHYR + 2;
   IF  COMMYR < 62 THEN DELETE;
   IF  COMMYR > 83 THEN DELETE;
   PROC SORT; BY TYPE;
   PROC MEANS NOPRINT;BY TYPE;
        VAR AQCST84 ;
        OUTPUT OUT = AVG
        N = NCLASS
        MEAN= MAQCST84
        SUM = SAQCST84;
DATA  CV;
   MERGE XX AVG;BY TYPE;
             IF FIRST.TYPE THEN GO TO MISS;
                  ELSE DELETE;
             MISS: ;
   PROC SORT;BY DCODE COMMYR TYPE;
   DATA ALL5;
    SET CV;
    IF CLASS = 'DD' OR CLASS = 'DE' OR CLASS ='DER'
  OR CLASS = 'FF' OR CLASS = 'FFG' THEN DCODE = 13;
             RTC = TONNAGE/MAQCST84;
             RPC = CREW/MAQCST84;
             RKWC = GENCAP/MAQCST84;
             RUC = 1/MAQCST84;
   PROC SORT;BY DCODE COMMYR TYPE;
   PROC MEANS ; BY DCODE;
             FREQ NCLASS;
        VAR RTC RPC RKWC RUC MAQCST84 ;
             OUTPUT OUT = SUMS
                  N = S1 S2 S3 S4 NCST
               MEAN = MRTC MRPC MRKWC MRUC S5
                SUM = S6 S7 S8 S9 SCST;
   DATA XX2;
        MERGE SUMS SLOPES; BY DCODE;
   PROC PRINT;
        VAR DCODE NCST SCST MRTC MRPC
        MRKWC MRUC DRTC DRPC DRUC DRKWC;
DATA XX3;
        SET XX2;
****************** Step 8  *********************
   GRTC = DRTC/MRTC;
   GRUC = DRUC/MRUC;
   GRKWC = DRKWC/MRKWC;
   GRPC = DRPC/NCST;
   W2TC = GRTC*NCST;
   W2UC = GRUC*NCST;
   W2KWC = GRKWC*NCST;
   W2PC = GRPC*NCST;
   W4TC = GRTC*SCST;
   W4UC = GRUC*SCST;
   W4KWC = GRKWC*SCST;
   W4PC = GRPC*SCST;
   PROC MEANS ;
        VAR W2TC W2PC W2KWC W2UC
            W4TC W4PC W4KWC W4UC;
        OUTPUT OUT = BSUM
        SUM =SW2TC SW2PC SW2KWC SW2UC
            SW4TC SW4PC SW4KWC SW4UC;
```

```
DATA XX4;
        SET SUMS ;
   PROC MEANS ;
        VAR NCST SCST;
        OUTPUT OUT = HIT
             SUM = SNSHPS SSCST;
DATA XX5;
      MERGE BSUM HIT;
   W2GRTC = SW2TC/SNSHPS;
   W2GRUC = SW2UC/SNSHPS;
   W2GRKWC = SW2KWC/SNSHPS ;
   W2GRPC = SW2PC/SNSHPS;
   W4GRTC = SW4TC/SSCST;
   W4GRUC = SW4UC/SSCST;
   W4GRKWC = SW4KWC/SSCST;
   W4GRPC = SW4PC/SSCST;
   PROC PRINT ;
        VAR W2GRTC W2GRPC W2GRKWC W2GRUC
            W4GRTC W4GRPC W4GRKWC W4GRUC;
/*
//
```

APPENDIX B

METHOD B TYPICAL COMPUTER PROGRAM

```
*******************************************************************
                         PROGRAM V
*******    This Program Creates Method B         *********
******* Growth Rates with Weighting Factor       *********
*******              WT1T (by Type)              *********
*******     The SAS Steps are explained in       *********
*******              Chapter IIIC                *********
*******************************************************************
***** Note: Class in this program is actually   ******
***** ship "type" as correctly described in     ******
*****             Chapter I.                    ******
*******************************************************************
//RD  JOB (1231,0196),'DOUG SMARTT',CLASS=C
//*MAIN ORG=NPGVM1.1231P
//  EXEC SAS
//FROM   DD DISP=(OLD,KEEP),DSN=MSS.S1231.GWUSAS2
//SYSIN   DD *
DATA   CV;
   SET FROM.DOUG;
***************** Step 1   *********************
        IF CLASS = : 'T' THEN DELETE;
        IF CLASS = : 'P' THEN DELETE;
***************** Step 2   *********************
   PROC SORT ;BY CLASS;
***************** Step 3   *********************
DATA   SEVEN8;
   SET CV;
        IF LNCHYR > = 76 OR LNCHYR = . THEN DELETE;
        IF RETYR = . THEN GO TO MISS;
             ELSE IF RETYR < 79 & RETYR > 1 THEN DELETE;
        MISS: ;
        YEAR = 1978;
        TOTOBS=_N_;
PROC MEANS NOPRINT; BY CLASS;
    VAR TOTOBS TONNAGE CREW GENCAP AQCST84;
   ID YEAR;
********     Step 4 for Year 1978 ***************
   OUTPUT OUT = T78
        N = TOTOBS NTON NP NKW NCST84
      MEAN = SKIP   MTON MP MKW MCST84
       SUM = SKIP1  STON SP SKW SCST84;
DATA   SEVEN9;
   SET CV;
        IF LNCHYR > = 77 OR LNCHYR = . THEN DELETE;
        IF RETYR = . THEN GO TO MISS;
           ELSE IF RETYR < 80 & RETYR > 1 THEN DELETE;
        MISS: ;
        YEAR = 1979;
        TOTOBS=_N_;
PROC MEANS NOPRINT; BY CLASS;
    VAR TOTOBS TONNAGE CREW GENCAP AQCST84;
   ID YEAR;
   OUTPUT OUT = T79
        N = TOTOBS NTON NP NKW NCST84
      MEAN = SKIP   MTON MP MKW MCST84
       SUM = SKIP1  STON SP SKW SCST84;
DATA   EIGHT0;
   SET CV;
        IF LNCHYR > = 78 OR LNCHYR = . THEN DELETE;
```

```
        IF RETYR = . THEN GO TO MISS;
             ELSE IF RETYR < 81 & RETYR > 1 THEN DELETE;
        MISS: ;
        YEAR = 1980;
        TOTOBS=_N_;
PROC MEANS NOPRINT; BY CLASS;
    VAR TOTOBS TONNAGE CREW GENCAP AQCST84;
   ID YEAR;
   OUTPUT OUT = T80
        N = TOTCBS  NTON NP NKW NCST84
      MEAN = SKIP   MTON MP MKW MCST84
       SUM = SKIP1  STON SP SKW SCST84;
DATA   EIGHT1;
   SET CV;
        IF LNCHYR > = 79 OR LNCHYR = . THEN DELETE;
        IF RETYR = . THEN GO TO MISS;
             ELSE IF RETYR < 82 & RETYR > 1 THEN DELETE;
        MISS: ;
        YEAR = 1981;
        TOTOBS=_N_;
PROC MEANS NOPRINT; BY CLASS;
    VAR TOTOBS TONNAGE CREW GENCAP AQCST84;
   ID YEAR;
   OUTPUT OUT = T81
        N = TOTCBS  NTON NP NKW NCST84
      MEAN = SKIP   MTON MP MKW MCST84
       SUM = SKIP1  STON SP SKW SCST84;
DATA   EIGHT2;
   SET CV;
        IF LNCHYR > = 80 OR LNCHYR = . THEN DELETE;
        IF RETYR = . THEN GO TO MISS;
             ELSE IF RETYR < 83 & RETYR > 1 THEN DELETE;
        MISS: ;
        YEAR = 1982;
        TOTOBS=_N_;
PROC MEANS NOPRINT; BY CLASS;
    VAR TOTOBS TONNAGE CREW GENCAP AQCST84;
   ID YEAR;
   OUTPUT OUT = T82
        N = TOTCBS  NTON NP NKW NCST84
      MEAN = SKIP   MTON MP MKW MCST84
       SUM = SKIP1  STON SP SKW SCST84;
DATA   EIGHT3;
   SET CV;
        IF LNCHYR > = 81 OR LNCHYR = . THEN DELETE;
        IF RETYR = . THEN GO TO MISS;
             ELSE IF RETYR < 84 & RETYR > 1 THEN DELETE;
        MISS: ;
        YEAR = 1983;
        TOTOBS=_N_;
PROC MEANS NOPRINT; BY CLASS;
    VAR TOTOBS TONNAGE CREW GENCAP AQCST84;
   ID YEAR;
   OUTPUT OUT = T83
        N = TOTCBS  NTON NP NKW NCST84
      MEAN = SKIP   MTON MP MKW MCST84
       SUM = SKIP1  STON SP SKW SCST84;
   DATA ALL;
        SET T78 T79 T80 T81 T82 T83;
   PROC SORT ;BY CLASS YEAR;
   DATA ALL1;
        SET ALL;
****************** Step 5   **********************
      RUC=NCST84/SCST84;RTC=MTON/MCST84;
          RKWC=MKW/MCST84;RPC=MP/MCST84;
            YEAR1 = YEAR - 1;
****************** Step 6   **********************
        D1= DIF(RUC);D2=DIF(RTC);D3=DIF(RKWC);D4=DIF(RPC);
****************** Step 7   **********************
```

```
        GRUC=D1/RUC;GRTC=D2/RTC;GRKWC=D3/RKWC;GRPC=D4/PPC;
    PROC SORT ;BY CLASS YEAR;
    DATA ALL2;
        SET ALL1;
            IF YEAR1='1977' THEN DELETE;
    DATA FIVE;
        SET ALL2;
            IF YEAR1<1978 THEN DELETE;
    PROC MEANS NCPRINT;BY CLASS;
        VAR GRUC GRTC GRKWC GRPC  ;
        OUTPUT CUT = ONE
        MEAN= M1CGRUC M1CGRTC M1CGRKWC M1CGRPC  ;
    DATA WEIGHT1;
        SET ONE;
    PROC MEANS NCPRINT;
        VAR M1CGRUC M1CGRTC M1CGRKWC M1CGRPC  ;
        OUTPUT CUT = TONE
        MEAN= M1GRUC M1GRTC M1GRKWC M1GRPC  ;
PROC PRINT DOUBIE;
 TITLE1 GROWTH FATES FOR ALL SHIPS;
 TITLE2  (EACH TYPE OF SHIP WEIGHTED EQUALLY(WT1T));
 TITLE3  (FIVE YEAR PERIOD);
        VAR M1GRUC M1GRTC M1GRKWC M1GRPC  ; /* //
```

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